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COST ESTIMATING CASES:
EDUCATIONAL TOOLS FOR COST ANALYSTS

THESIS

Kerrie G. Schieman, Captain, USAF
James R. Passaro, Captain, USAF

AFIT/GCA/LAS/93S-5

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COST ESTIMATING CASES: EDUCATIONAL TOOLS FOR COST ANALYSTS

THESIS

Presented to the Faculty of the Graduate School of Logistics and Acquisition Management

of the Air Force Institute of Technology

Air Education and Training Command

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Cost Analysis

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September 1993

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James R. Passaro and Kerrie G. Schieman

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Abstract

The goal of this research effort was to develop educational cases that would bridge the gap between the theory and principles of cost estimating currently taught in the Air Force Institute of Technology (AFIT) Graduate Cost Analysis (GCA) curriculum and the real world of cost estimating in the acquisition arena.

To achieve these goals, the following research objectives were investigated: (1) Identify cost estimating skills that graduates of the AFIT GCA curriculum are expected to possess. (2) Assess the relative importance of the identified cost estimating skills. (3) Select weapon system scenarios that are relevant, interesting, and facilitate student performance of identified cost estimating skills. (4) Provide cases based on realistic scenarios that will facilitate student learning of important cost estimating skills.

The cases developed in this research effort were implemented in the summer quarter 1993 GCA seminar class. Feedback from seminar students and Air Force cost estimating organizations was collected to measure the overall effectiveness of these cases in facilitating student learning. The results show that the cases developed in this effort are effective in developing the AFIT GCA students' abilities to apply cost estimating techniques.

COST ESTIMATING CASES:
EDUCATIONAL TOOLS FOR COST ANALYSTS

I. Introduction

General Issue

For the last 50 years the Department of Defense (DoD) has relied on a mixture of evolutionary and revolutionary technological advantages to offset the capabilities of numerically superior adversaries (1:4). Fielding technologically superior systems has been our *competitive advantage* in the business of war (1:4). Throughout this period, the DoD acquisition process has provided the vehicle for bringing these concepts of technological superiority to fruition on the battlefield. Due to the large dollar values associated with the development of any major weapon system, the acquisition process has historically been heavily scrutinized by Congress and the general public. In recent years, however, this attention has escalated significantly as our nation attempts to come to grips with a defense budget that is projected to continue shrinking into the year 2000 (2:36). Correspondingly, the cost estimates that support major weapon system program decisions have become increasingly important.

Cost estimating is an essential aspect of the acquisition process and is used throughout every phase in the life of a weapon system. The National Estimating Society has defined cost estimating as "the art of approximating the probable work or cost of something based on information available at the time" (3:14). A partial list of terms related to the cost estimating field is provided in Appendix A. The responsibilities of DoD acquisition cost analysts have become increasingly significant and correspondingly complex as the acquisition environment continues to evolve in this era of austere funding.

Each cost estimating effort is unique in that the specific tools and techniques employed vary significantly depending on:

1. The type of weapon system.
2. The phase of the acquisition process the weapon system currently inhabits. (i.e., concept exploration, demonstration/validation, engineering and manufacturing development, production, or operations and support).
3. The amount of data available.
4. The amount of time provided to conduct the analysis.
5. The phase of the weapon system life cycle being estimated.

The selection of the proper tools required to meet the demands of the above factors requires substantial judgment, complemented by corresponding experience, on the part of the cost analyst preparing the estimate.

This complexity has resulted in a need for instructional methods that can equip DoD cost analysts with a wide range of analytical tools to meet the demands of this dynamic environment. At this point the terms cost estimating *techniques* and cost estimating *skills* need to be addressed. A technique is defined as "a technical method of accomplishing a specific aim" (4:1335), while a skill refers to "the ability, coming from one's knowledge, practice, aptitude, etc., to do something well" (5:2348). For example, parametric cost estimating is a technique, while the ability to build automated spreadsheets is a skill. The acquisition cost analyst must have adequate knowledge of the various estimating *techniques*, but it is his *skill* in applying those techniques that will make him successful. Thus the focus of this research effort is on developing students' cost estimating skills through the proper application of cost estimating techniques.

Many of the cost estimating techniques used in DoD acquisition are currently being addressed in the Air Force Institute of Technology (AFIT) Graduate Cost Analysis (GCA) curriculum. The GCA curriculum consists of 64 hours of graduate level instruction.

Twenty-seven of those 64 hours are directly aimed at teaching cost analysis techniques and developing the students' estimating skills (6). A brief description of the courses that make-up the 27 hours of cost analysis instruction is provided in Appendix B (7).

The AFIT GCA program is sponsored by the Deputy Assistant Secretary of the Air Force, Cost and Economics (SAF/FMC). During the 1992 curriculum review with SAF/FMC, it was determined that AFIT students should receive more opportunities to practice the application of the cost estimating techniques taught in the curriculum. This need was also substantiated by recent GCA graduates, who provided feedback to the GCA program manager at AFIT (6). This curriculum review led to the decision to redesign one of the existing AFIT courses to emphasize the application of cost estimating techniques within the acquisition framework. It was clear that a traditional lecture-type course would not provide the level of learning dictated by *application* learning objectives. The GCA program manager decided to pursue the case method of instruction to meet this need. This led to the decision that cost estimating cases should be presented in a seminar class format to provide students with a realistic background to practice the application of cost estimating skills. Under the sponsorship of SAF/FMC, this thesis effort was initiated to develop such cases.

Specific Research Problem

Many GCA students graduate with under-developed skills to properly apply the tools and techniques they have been exposed to at AFIT. This is because curricula traditionally have emphasized the theoretical development of cost methods more than *real world* cost estimating applications. Feedback from the program sponsor indicates that the GCA program would be improved if the current curriculum was supplemented with opportunities to apply the various techniques.

Research Objectives

Cost estimating cases presented in a seminar format would help develop the skills of the students to properly apply cost estimating techniques in the acquisition arena. As will be discussed in Chapter II, cost estimating cases that could meet this problem currently do not exist. This thesis will utilize the case method to develop educational cases to be used in the present GCA curriculum. The cases will be presented to the current GCA students in the summer quarter (1993) seminar class. To address this problem, the objectives of the research effort are to:

1. Identify the cost estimating skills that graduates of the AFIT GCA curriculum are expected to possess.
2. Assess the relative importance of the identified cost estimating skills.
3. Select weapon system scenarios that are relevant, interesting, and facilitate student performance of identified cost estimating skills.
4. Provide cases based on realistic scenarios that will facilitate student learning of important cost estimating skills.

Scope of the Research Effort

There are several factors which will shape the overall scope of this research effort:

1. The cases will focus specifically on cost estimating applied within the acquisition process. Cost analyses performed at base-level organizations (i.e., economic analyses, cost benefit analyses) will not be addressed. Since the vast majority of GCA graduates are placed at one of the following locations--the Aeronautical Systems Center (ASC), the Space and Missile Systems Center (SMC), the Electronic Systems Center (ESC), and the Air Force Cost Analysis Agency, the cases will only involve scenarios at these locations.

2. The cases will focus on the acquisition of Air Force weapon systems and will not address acquisition within other defense departments or DoD agencies.

3. The cases will address common cost estimating tools and techniques and will not address tools or techniques that are unique to one specific product center.

4. Due to the effort involved in building cases and the amount of time available to implement the cases in the seminar class, the GCA program manager decided that the construction of three cost estimating cases would be sufficient (5).

Thesis Overview

The remainder of this research effort will seek to accomplish the specific research objectives established earlier in this chapter. Chapter II consists of a review of the relevant literature available on cost estimating skills, the case writing process, as well as a review of existing cost estimating cases in the DoD. Chapter III describes in detail the methodology used to identify pertinent cost estimating skills and develop the cost estimating cases. Chapter IV provides an in-depth analysis of the overall case development process, and presents the results of our efforts--the student cases. Finally, Chapter V provides a summary of the research effort and final conclusions concerning the cases.

II. Literature Review

Overview

This chapter provides a review of publications and other literature addressing cost estimating skills and the case method of instruction. It begins with a review of the existing literature concerning the necessary skills of cost analysts. This is followed by a summary of the process used to construct educational cases. Cost estimating cases currently being used in DoD education and training will then be reviewed to gain any insights into the case development process. Finally, the case-method of instruction will be introduced as the method of filling the application gap currently existing between AFIT instruction and the duties expected of GCA graduates.

Cost Estimating Skills

The specific duties of cost analysts who graduate from the GCA program will vary significantly depending on their assignments following graduation. For example, a graduate who is placed in one of the program offices at an Air Force Materiel Command (AFMC) product center will generally be responsible for estimating the cost of a specific portion of a weapon system. On the other hand, a graduate assigned to the financial management staff of a product center will have responsibilities ranging from conducting research of cost models/estimating tools to providing cost estimating support to various program offices. Additionally, AFIT graduates are occasionally placed in AFMC Air Logistics Centers (ALCs) or assigned to the AFMC headquarters staff--duties at these locations are significantly different than those already mentioned. For instance, a cost analyst assigned to an ALC will often be heavily involved with operation and support (O&S) cost estimating. In addition to job assignment, factors such as the type of weapon system and the phase of the program also affect the application of cost estimating techniques. According to the GCA program manager, the majority of cost analysis graduates are placed in one of the AFMC program offices (6).

The amount of published material available which addresses the skills required of acquisition cost analysts is minimal--due in part to the diversity of skills required at the different job sites. In fact, a search of the literature revealed only two documents that specifically addressed the range of acquisition cost estimating skills required in acquisition. These are 1) The Air Force Systems Command Cost Estimating Handbook (AFSC Cost Handbook) and 2) a report prepared by the Deputy Assistant Secretary of the Air Force, Plans, Systems, and Analysis (SAF/FMP), subject *Training Requirements for Acquisition Personnel in the Business, Cost Estimating, and Financial Management Position Category*.

The AFSC Cost Handbook was prepared for AFSC (now AFMC) by The Analytical Sciences Corporation (TASC). The Handbook consists of 6 volumes. Volume one focuses on the general principles of cost estimating, providing information that is equally applicable to all Systems Command cost estimating activities and organizations (8). Volumes two through six are specialized publications that focus on the unique aspects of the various product centers that were in existence at the time the Handbook was created. For example, volume two addresses aeronautical system cost estimating, and chapter five addresses missile system cost estimating. While volume one identifies cost estimating techniques, the relative importance or frequency of use of the techniques is not addressed.

The SAF/FMP report also presents a large number of cost estimating skills, but in a much different context. The SAF/FMP report was initiated to develop course requirements for the certification of acquisition personnel as directed by the Defense Acquisition University (DAU) (9). DAU is an organization which works with consortium schools such as AFIT, and with functional boards comprised of members from each service, to help implement the Defense Workforce Improvement Act (DAWIA). Cost estimating is one of three tracks which will be listed under the Business, Cost Estimating, and Financial Management Functional Board in DoD 5000.52-M, Career Development Program for Acquisition Personnel. At the time of this writing, the DAU consortium schools had just finished their review of cost estimating duties/tasks. This review was accomplished by subject matter experts from program offices, product center staffs, and cost agencies representing each of the three services. Unlike the AFSC Cost Handbook, the DAU study does not provide any detailed discussion of the skills, rather it simply lists the skills targeted for eventual inclusion in acquisition financial management courses. The DAU study presents 57 broad cost analyst duties, and divides them into detailed sub tasks.

Twenty six of the 57 skills listed in the DAU study are also addressed in the AFSC Cost Handbook. Table 1 summarizes the 26 shared skills.

TABLE 1
Skills Addressed in AFSC Handbook and SAF/FMP Report

1. Prepare life cycle cost estimates.	14. Analyze and document variances or inconsistencies in cost estimates.
2. Prepare baseline cost estimates.	15. Prepare risk analyses.
3. Prepare independent government cost estimates.	16. Develop and analyze acquisition reports.
4. Develop cost data to be used in developing cost	17. Develop inflation factors.
estimates and analysis.	18. Collect and analyze operating and support data.
5. Determine cost impacts of production schedules.	19. Present and defend cost estimates and analyses.
6. Determine cost impacts of deployment schedules.	20. Develop cost models.
7. Apply learning curve theory to develop program cost estimates	21. Develop risk models.
8. Develop and apply work breakdown structures.	22. Perform statistical/quantitative analyses.
9. Evaluate contractor performance using contractor reports.	23. Perform parametric, analogous, and engineering analysis.
10. Analyze costs for allowability, allocability, and reasonableness.	24. Develop cost estimating relationships.
11. Perform production rate analysis.	25. Evaluate off-the-shelf cost models.
12. Convert cost estimates from constant/base-year dollars to current/then year dollars.	26. Develop design to cost estimates.
13. Evaluate cost proposals.	

The preceding table provides an overview of the various skills required of acquisition cost analysts. Obviously, each of the above skills can be further divided into several more detailed sub-tasks.

Case Method of Instruction

The Case Method Defined. The case method of instruction has been used extensively by business schools and management development centers as a tool for training managers. The first book of written cases was published by the Harvard Business School in 1921 (10:13). Although it was originally developed in the United States some seventy years ago, its use has become widespread in colleges and universities throughout the world (11:99).

> The case method is a system of instruction built on the premise that people are most likely to retain and use what they learn if they reach understanding through guided discovery. Along the way, trainees refine analysis skills, develop the will to take risks in the face of uncertain outcomes, and come to know their own strengths, weaknesses and talents. (12:46)

One distinction that must be made is the difference between the case method and a case study. A case study is a chronological history of a decision situation, with a complete discussion of the relevant issues and the outcome. The case method, on the other hand, "is more like an editorial, which directs the reader toward a way of thinking about an issue" (12:46). Thus, while a case study presents the historical solution to a decision scenario, the case method leaves the solution open to the student's individual analysis and interpretation. The case method is a technique that attempts to submerge the student in the environment of an actual organizational decision maker and forces the student to react as if the situation was in fact the real thing (13:69).

The Case Writing Process. There have been innumerable reviews, critiques, and analyses published concerning the case method of instruction. However, compared to the plethora of information which addresses the use of the case method of instruction in the classroom, considerably less has been written on how a case should actually be constructed and written. Provided below is a summary of the major steps of the case writing process as suggested by Michiel R. Leenders and James A. Erskine, in their 1989 book Case Research: The Case Writing Process (9:10-107).

1. The Origin of the Case--Setting Learning Objectives. The specific formula for initiating the case subject varies in relation to several factors: the author(s) background, the proposed purpose of the case, and the educational background of the targeted students. Regardless of the impact of these factors, it is generally accepted that a good case begins with the development of appropriate learning objectives. Additionally, the development of learning objectives must be grounded in research--the writer must be concerned with his understanding of the practitioner's problems (9:10). Moreover, it is often helpful to develop learning objectives while considering specific decisions that the writer wants the student to be faced with. For example, one decision for a cost analyst may involve choosing an appropriate estimating methodology, given applicable cost data.

2. Establishing Leads. After determining the required learning objectives, the next step is to find approachable organizations where these objectives can be framed in issues which the organization has faced. This process of prospecting for potential case scenarios can be referred to as establishing leads. It is important during this phase of the process to be open to all potential sources of information--functional organizations, educational branches, and informal personal contacts. Often the best source for a potential scenario is to go directly to an organization and talk to them about your needs.

3. Data Collection. Once the case writer or case writing team has successfully established contact with a potential source of information, the stage is set for data to be collected. The data collection process must be sufficiently planned before attempting to gather the information. An outline based upon the targeted learning objectives can be instrumental to ensuring all of the necessary data is obtained. The format for the data collection effort should focus on the following potential sources:

1. Published data outside the organization.
2. Internal working documents.
3. Personal interviews with personnel inside the target organization. (9:40)

It is important throughout the data collection effort that the case writer focus on the substance of the learning objectives or decisions that the case will attempt to simulate.

4. Content. After the relevant data is collected, it is appropriate for the case writer(s) to begin constructing drafts of the case. "Cases can vary in difficulty from short, one-page descriptions focusing on a specific micro problem, to sequential cases which have numerous subparts focusing on complex issues and relationships" (14:27). The structure of a written case is highly interpretive, and depends on several factors including the degree of difficulty of the targeted learning objectives, the amount of data available (either historical data or data that can be simulated), and the personal writing style of the case writer. In any case writing effort, the writer must continually keep the perspective of the students in mind.

> The student's time is limited and even though data in the real world are highly disorganized and random, [a senior cost analyst] has a way of organizing the environment that he or she has built him or herself, whereas the student doesn't. So to give the student a fair shake and a decent decision, you have to organize it; no magic numbers in the footnotes etc.--that is unfair. Educationally, it gets you nowhere. Highly complex cases

> really don't do that much for the student. If you can't say it in ten to fifteen pages, it's probably not worth saying. (9:43)

The case writer must be familiar with the experience level of the students. Students with little or no background in the subject matter will require more prompting in the case to guide the student in the decision making process. How much guiding is appropriate is a subjective decision that must be based on the writer's awareness of the students' background. Nevertheless, there are a few general pieces of information that are normally included in every case; such as background on the people, the problem, and the organization. Once again, it is the case writer's responsibility to determine how much background material is needed to provide setting and context without giving so much information so as to block the students ability to understand the situation.

5. Presentation. Presentation is different from content in that presentation involves determining the order and format in which information will be presented to the student. It is often helpful to think of the case as having a certain structure or anatomy of its own (9:47). *Time structure* refers to the time sequence in which the business situation takes place. The case can be organized based on the sequence of events that occurred in the organization. In any event, the time sequence of the case must be fairly clear to the student. Additionally, there is a *narrative structure* to most cases. The things that happened and the circumstances of their occurrence must be narrated in some understandable pattern. In fact, a case can be approached like a play that opens in the middle of the story and uses flashbacks to describe the situations that led up to the opening scene (12:46). It is important that the case be written in such a manner as to hold the student's interest and motivate him or her to perform.

> For the case to be a really living thing and for the student to forget that it's artificial, there must be drama, there must be suspense. The skillful case

writer will build this up. A case isn't just a bland narrative where there's no question or issue. (9:48)

Concerning the order in which information is presented in the case, it is often advisable to begin with an opening scene or situation, focus in on a particular problem, and then provide the appropriate background data as needed. The writing process should also include the use of extensive drafting, editing and proofreading to ensure the case is clearly and concisely composed. In any event, the process of writing cases varies considerably from person to person.

Cost Estimating Cases Currently in Use by DoD Education and Training Institutions

The Army, Navy and Air Force all have a need to train their acquisition cost analysts in the various skills of cost estimating. The AFIT Professional Continuing Education (PCE) program provides the largest number of cost estimating training courses in the Air Force. The Army conducts the majority of its cost estimating training through the Army Logistics Management College (ALMC) located at Fort Lee, Virginia. The Navy, on the other hand, utilizes ALMC, AFIT, and various DoD contractors to fulfill its cost training requirements (15).

Ten cost analysis courses are provided through the AFIT PCE program, ranging from an introduction to the principles of cost analysis to an examination of advanced quantitative techniques (16:35-69). Five of these courses use some type of cost estimating case to allow students to apply the concepts taught in the courses. The length of these courses range from 1 to 3 weeks. Four characteristics were developed to summarize the content of the cases:

1. Skills - Translates the case tasking into specific skills (techniques or tools) students must understand or apply.

2. Phase - Lists the phase(s) of the targeted acquisition program that the student is responsible for estimating.

3. Case Format - Briefly describes the flow of the case.

4. Scenario - Describes the setting, if any, in which the case takes place. Also describes the type of system being estimated.

Table 2 summarizes the characteristics for each case. Definitions of all acronyms and terms that may be unclear to the reader can be found in appendix A.

As shown in Table 2, each case has its own unique characteristics that define its content. The most notable differentiation that can be made between the cases concerns the amount of realism injected in the cases. The SYS 227 and QMT 551 cases provide detailed program and system background data to give the student a *feel* for the system and program. The other cases make no real attempt at this effort. Additionally, none of the cases use dialogue to bring the case to life. In fact, all of the cases have instructional guidance embedded in the cases, which serves as a constant reminder to the student that this is indeed an artificial scenario. This lack of realism may be due in part to the environment in which these cases are administered. Each case represents only a subset of the overall learning experience targeted for the courses. Thus the cases are not meant to stand alone as instructional tools. It should be noted that the QMT 551 cases were developed by an independent consultant. The remainder of the cases were developed in-house by the AFIT PCE faculty. Also, student feedback on the QMT 551 cases has revealed significant shortcomings of these cases. Specifically, there are many logical discontinuities in the data, as well as some data inconsistencies identified by the PCE staff (17).

TABLE 2
Summary of Existing Cost Estimating Cases

COURSE	SKILLS	PHASE	CASE FORMAT	SCENARIO
QMT 175 Principles of Cost Analysis	Spreadsheet building Learning curves CER building Regression analysis Wrap rates Documentation	Production	Case broken into estimating sections which list specific data.	No opening scenario provided. Case involves a theoretical cargo aircraft.
QMT 345 Quantitative Techniques for Cost and Price Analysis	Data normalization Regression analysis CER building Overhead rates Statistics Time series analysis	Production	Case broken into estimating sections which list specific data. Student guidance provided throughout.	A simulated tasking letter from the cost estimating chief opens the case. Case involves a theoretical missile.
SYS 227 Financial Mgt in Weapon System Acquisition	WBS development Data normalization Learning curves Spreadsheet building Complexity factors Time phasing	Production	Case broken into sections which list specific data. Detailed system background and student guidance provided.	A simulated program management directive is provided to open the case. Case involves a theoretical air-to-air missile.
QMT 551 Advanced Cost and Economic Analysis	Data normalization Learning curves Complexity factors Cost model application	Life cycle estimate	Opens with learning objectives. Extremely detailed system and program background.	No opening scenario. Case involves a theoretical fighter aircraft.
ALMC Case (Bradley Fighting Vehicle Scenario)	Cost factor cross-check CER development	O&S	Opens with program status. Provides Case requirements and gives cost data.	No real scenario. No flow throughout the case. Case involves the Bradley Fighting Vehicle.
ALMC Case (Hawk Missile Scenario)	CER development Statistical tests Data normalization Time phasing Learning curves	Production	Opens with system background. Provides assumptions and case requirements.	No scenario given. Simply states program background and provides CER data.

Summary

This chapter reviewed literature and publications related to cost estimating skills and the case development process. Additionally, several cost estimating cases currently being used in the Air Force were examined. This literature review revealed three important themes: First, there is a wide variety of cost estimating skills that need to be addressed through formal education and training. Second, the case development process is highly subjective, and should be tailored to meet the specific needs of the case writer(s). Additionally, any case writing effort should begin with the development of specific learning objectives. Lastly, there is a need for realistic cases to be developed that can provide students with an opportunity to practice the application of cost estimating techniques in an environment that simulates the acquisition arena. The use of cases that are realistic and stimulating to the student can bridge the gap that currently exists between academia and the real world.

III. Methodology

Overview

This chapter discusses the methodology used for this research effort. Research was conducted in three phases. The first phase involves identification of cost estimating skills to be addressed in cases. The second phase consists of a questionnaire directed at the product centers and the Air Force Cost Analysis Agency (AFCAA) to meet four objectives: (1) validate and refine the identified skills as needed, (2) rank the relative importance of the identified skills and (3) obtain leads on potential weapon system scenarios for cases, and (4) based on the questionnaire, select skills to be used in the cases. The third and final phase concerns the development of the targeted cases.

Phase 1: Identification of Cost Estimating Skills to be Addressed in Cases

The purpose of this phase was to develop a tentative list of cost estimating skills to use as a baseline for the follow-on field questionnaire. This list of skills would then be sent to the product centers and the AFCAA to provide them with a baseline for determining which cost estimating skills they perceived to be most important. Skills were identified using two activities: (1) a brainstorming session between the thesis authors and (2) personal interviews with experienced cost estimating personnel. The AFSC Cost Handbook provided the starting point for the brainstorming effort, as each chapter of the handbook was reviewed for potential cost estimating skills. The result of the brainstorming session was an initial list of 35 potential skills, the majority of which came directly from the AFSC Cost Handbook.

The next step was to validate the brainstormed list by discussing the list with experienced cost estimators. The advisors for this thesis effort (Major Wendell Simpson and Captain Tom Tracht) were selected for their backgrounds in the estimating arena.

Additionally, the advisors had estimating experience with two of the three existing product centers, thus providing additional insights into potential product center unique skills. The result of these discussions was an expanded list of cost estimating skills to be used as the baseline for the follow-on questionnaire. These skills were restructured as specific objectives to better clarify the context within which the skills will be applied. Provided below is a summary of the objectives that were selected for the questionnaire.

1. Prepare appropriate cost estimating documentation.
2. Develop computer spreadsheets to automate weapon system cost estimating.
3. Utilize normalization techniques.
4. Understand the various time-phasing techniques.
5. Interpret cost performance reports.
6. Choose an appropriate methodology and perform a cross-check.
7. Understand the purpose and uses of a work breakdown structure (WBS).
8. Use a parametric methodology in developing a cost estimate.
9. Use the analogy method in developing a cost estimate.
10. Use a grass roots methodology in developing a cost estimate.
11. Summarize the elements that comprise an operating and support cost estimate.
12. Understand the elements that comprise Other Government Costs (OGC) and their impact on the total weapon system cost estimate.
13. Compute cost risk using a given model.
14. Prepare an estimate briefing for a milestone review.
15. Compare cost estimates to budget available and develop possible course of action (what-ifs) to reconcile.

16. Explain the purpose and use of initial spares.

17. Construct wrap rates.

18. Know the elements that comprise a Cost Analysis Requirements Document.

Phase 2: Product Center and AFCAA Questionnaire

As stated in the introduction, this phase consisted of the development of a questionnaire to satisfy the four objectives discussed below. The questionnaire was distributed to the Director of Cost for each of the product centers as well as the Commander of the Air Force Cost Analysis Agency (AFCAA). The questionnaire requested that a broad spectrum of cost analysts be selected to respond to respond to the questionnaire. Specifically, it was suggested that questionnaire participants reflect the range of estimating experience (junior to senior). Additionally, a mix of military and civilian personnel, along with inclusion of at least one prior GCA graduate, was requested. A copy of the questionnaire is provided in Appendix C.

Objective 1 - Validate/Refine Skills. Each of the organizations surveyed were requested to review and comment on the skills proposed, and add any additional skills not already identified.

Objective 2 - Rank Skills. Each of the organizations surveyed were requested to rank the relative importance of the cost estimating skills, including any additional skills identified by the agency. This ranking was accomplished by numerically ordering the skills. For example, if the fifth skill on the list was the most important, it should have been ranked number 1. The second most important skill listed should then have been ranked with the number 2, etcetera.

Objective 3 - Obtain Leads on Weapon System Scenarios. Since realism was determined to be a significant element of the case development process, it was determined that the selection of relevant and interesting weapon system programs was important to the research effort. Therefore each of the surveyed organizations was requested to provide possible leads on weapon system programs that they felt would provide interesting backdrops for a case, as well as adequate data.

Objective 4 - Select Skills to be Used in Cases. The results of the questionnaire were analyzed to determine which skills were most important for inclusion in the cases. Obviously not all relevant cost estimating skills could be addressed, so the organizations' rankings of the skills were used to differentiate the skills that were finally selected. Specifically, those skills representing the top 50% of rankings from all of the field agencies surveyed were selected for inclusion in the cases. These skills were also cross-checked against the SAF/FMP report as an additional measure of skill validity. A draft copy of the SAF/FMP report was used for this cross-check as the final report was not yet available (16).

Phase 3: Develop Cases

This phase consisted of 6 tasks:

1) Select weapon system programs to use as case scenarios.
2) Develop learning objectives for each scenario based on identified skills.
3) Write the cases.
4) Develop solutions for the cases.
5) Develop teaching plans for the cases.
6) Evaluate the cases.

Task 1 - Select Weapon System Programs to Use as Case Scenarios. This task began with the construction of criteria to judge the usefulness of the possible weapon system scenarios. The criteria selected were 1) data availability, 2) program phase, 3) estimating environment, and 4) age of the program. Data availability addresses two questions. First, is the data accessible (i.e., is it classified or sensitive)? If the data is accessible, is it convenient to retrieve? For example, is the data available in the local area, or is it stored in another part of the country? The second criteria, program phase, refers to the weapon system's position in the acquisition process (e.g., the concept exploration phase). This step seeks to identify weapon system scenarios that represent different phases of the acquisition process, so that students will be exposed to a wide range of estimating situations. Estimating environment identifies the organizations involved with the estimating effort (i.e., AFCAA or one of the product centers) and the type of system (e.g., aircraft or electronic system, for example). The last criteria provides a measure of how current the weapon system is, based on when the program was initiated and whether it is still on-going.

In addition to the questionnaires, personal contacts from two of the product centers were established to identify possible scenarios. Mr John Allen, former Chief of the ASC Cost Analysis Avionics Branch (ASC/FMCC) (18), and Captain Tracht, former analyst on the SMC Cost Analysis Staff, provided input to this process (19). After receiving a list of potential scenarios from Mr Allen, research was conducted at the ASC Cost Library to determine if the scenarios satisfied the criteria stated above. Captain Tracht identified one program that satisfied all of our criteria. The author's (Captain Kerrie Schieman) personal experience in weapon system acquisition was also useful in identifying possible programs. Based on the program data collected, specific weapon system scenarios were selected.

Task 2 - Develop Learning Objectives for Each Case Based on Identified Skills. Bloom's taxonomy was used to translate the cost estimating skills identified by the field questionnaire into learning objectives (20:201-207). For example, the skill of *analogous estimating* was translated to *use an analogous methodology.* Care was taken to match skills to the scenarios based on the phase of the program and the data available. For instance, the skill of parametric estimating was matched to the weapon system scenario that involved the concept exploration phase of the acquisition process, as this is the time-frame where parametric estimating is most often utilized.

Task 3 - Write the Cases. This task was approached with a 7 step process developed by the authors based on their review of the case writing literature presented in chapter 2. The first three steps included the development of the scenario, program background, and system description. These three elements provide the framework for the entire case, and thus can be referred to as the ***setting*** of the case. The remaining steps provide the student with all of the supporting documentation required to take the student through the learning objectives. These steps include development of the acquisition plan, ground rules and assumptions, tasking, and supporting data. These elements comprise the bulk of the analysis and thus can be referred to as the ***content*** of the case.

Data collection sheets were used to construct the overall layout of each case (21). These data collection sheets were modified by the authors to coincide with their case writing approach. A sample data collection sheet modified for this research effort is provided in Appendix D. The setting was important to each case as it served three basic purposes: 1) inspire student interest in the case, 2) inject realism into the case, and 3) provide necessary background information. The content of the case is obviously crucial as the student cannot accomplish the learning objectives without this information. A large portion of this data was extracted (and subsequently masked) from cost estimating documentation. However, a smaller amount of content information had to be contrived by the authors. The writing process itself iterated between writing the content and writing the setting. For example, the development of supporting cost data for a case often resulted in many changes to the previously drafted background and ground rules/assumptions sections. Thus several drafts of each case were constructed before a final case could be completed.

Task 4 - Develop Solutions. Developing solutions involved executing the specific tasks outlined in each case. It should be noted that the cases require judgments by the students. The solutions constitute the authors' perception of the *best* answers to the issues presented in the cases. These solutions should not be considered the only answers--cost estimating is a creative process and different answers to problems can be developed based on the individual analyst's experience and judgment. The development of solutions resulted in cosmetic changes to the cases based on the insights gained by actually performing the case.

Task 5 - Develop Teaching Plans. The case method of instruction involves more than the development and implementation of cases. Students must be provided with the necessary tools and techniques before executing a case. Thus the case method of instruction can use several different instructional vehicles to complement the accomplishment of the desired learning objectives. One such vehicle is the teaching plan. The format of the teaching plans was developed based on input from the GCA program manager (6). Specifically, four sections were developed--1) learning objectives, 2) resources required, 3) topics to be discussed, and 4) possible sources.

The learning objectives consisted of the objectives previously established for each case. The second section of the teaching plan informs the instructor what types of resources the student needs to accomplish the stated learning objectives. For example, the use of computers, specific software packages, and other analytical tools. The third section, topics to be discussed, delineates those areas which students need to understand before being able to execute the case. Finally, as an additional benefit to the instructor, potential sources of information were provided. For instance, publications were listed which address the various topics. The teaching plans for each case are provided in chapter four.

Task 6 - Evaluate Cases. The cases were evaluated based on four criteria: clarity, realism, difficulty, and student learning. These criteria were selected based on their ability to measure the overall effectiveness of each case. The first criteria, clarity, attempts to define the comprehensibility of the case--i.e., can the student understand the requirements of the case and determine how to meet those requirements? Student input was used to measure this criteria. Specifically, after the final draft of each case was completed, two students were asked to review the clarity of the case. The two students were selected based on their experience with acquisition cost estimating. For each review an experienced and inexperienced student was chosen. This reduced the amount of bias that could be introduced by the student's past experience or lack of experience. Student feedback was provided in the form of a questionnaire (Appendix E) designed to evaluate the cases' overall clarity. Student feedback was analyzed by using summary tabulations.

The second criteria, case realism, refers to the case's ability to simulate the acquisition cost estimating environment. A questionnaire of subject matter experts was used to measure this criteria. This questionnaire was distributed to the Director of Cost for each of the product centers, the AFMC Director of Cost, and to the Commander of the Air Force Cost Analysis Agency. The questionnaire was designed to determine how well each of the various sections of the case (i.e., scenario, ground rules/assumptions, background) mirror actual situations that occur in the acquisition environment. It should be noted that these surveys were informal in the sense that they consisted of open ended questions designed to solicit narrative feedback. These were not formal surveys designed to solicit response data that could characterize some population--instead, they were designed to get feedback from specific organizations. A copy of the questionnaire is provided in Appendix F. To summarize the results of the questionnaire a descriptive meta-matrix analysis was employed. "Meta-matrices are master charts assembling descriptive data from each of several sites in a standard format" (22:152). The basic idea of a meta-matrix is to include all *relevant* data--they are especially useful when summarizing descriptive data from multiple sites (22:152).

The third criteria, case difficulty, was collected in the form of a questionnaire that evaluated the student's perception of the overall difficulty of the case. The questionnaire attempted to quantify difficulty by measuring the amount of time students spent on the case and their perception of case complexity. The median value for the hours spent and the median value for the complexity ratings were calculated to develop composite rankings of case difficulty. Frequency distributions were also developed to illustrate the range of time spent on each case. An assessment of case difficulty is important because a case that is overly simplistic can diminish its overall effectiveness. Additionally, a case that is too taxing can result in significant student frustration and subsequently impede learning. A copy of the questionnaire is provided in Appendix G.

The final criteria used to analyze the cases was student learning. Student learning attempts to determine whether or not the students met the desired learning objectives of the cases. The device used to measure learning was the student solutions required by each case. Each student's solution was evaluated by the authors to determine if the various techniques embedded within the learning objectives were properly demonstrated. Specifically, if the solutions demonstrated the students developed logical methodologies and executed them properly, then it was surmised that student learning occurred.

Summary

This chapter presented the methodology used in conducting this research effort. Three phases of research were introduced. The first phase outlined the various steps used to identify cost estimating skills to be addressed in the cases. Second, the methodology used to survey several cost estimating organizations throughout the Air Force was described. Finally, the six step approach used to develop the cases was outlined.

IV. Analysis and Results

Overview

This chapter presents the results of building three cost estimating cases for use in the summer quarter 1993 GCA seminar course at AFIT. First, specific skills (expressed in the form of learning objectives) were analyzed and selected for use in the cases. Second, weapon system programs were identified and selected for use as the background for the three cases. Finally, the results of the case development process--the final cases with solutions, along with an analysis of the results of implementing the cases--are presented. Each of these efforts follows the methodology delineated in Chapter III.

Selection of Cost Estimating Skills to be Addressed in Cases

As described in Chapter III, this effort began with the use of various reference documents, brainstorming, and personal interviews with experienced estimators. After several iterations a composite list of skills was developed and transformed into specific learning objectives. These objectives were then sent to various cost estimating organizations for review. Eighteen major skills were outlined in the questionnaire and the respondents ranked them from 1 (most important) to 18 (least important). They were also given the opportunity to add any additional skills not already identified.

Twenty questionnaires were returned from the various product centers and AFCAA. Table 3 summarizes the number of responses from each of the field agencies.

TABLE 3
Learning Objective Questionnaire Responses

AFCAA	ASC	ESC	SMC
11*	5	0	4

* Four of the AFCAA respondents did not rank the objectives in the manner specified in the questionnaire. This input was reviewed but not included in the final questionnaire results since the data could not be normalized to correspond with the other inputs.

To summarize the questionnaire results a composite score was calculated for each objective. First, each objective was evaluated by summing the amount of number one rankings, number two rankings and so on. The next step was to apply the weighted ranking to the objectives. For example, if an objective received four number one rankings then the weighted ranking would be 72 (4*18)--based on the 18 total skills. These rankings were then summed for all objectives to arrive at composite scores. The spreadsheet used to perform the above calculations is provided in Appendix H. The final results were compared and summarized in Figure 1. A short description of each objective is provided in Table 4 for reference (a detailed description can be found in Appendix C).

As requested in the questionnaire, several of the respondents provided additional skills they felt were important, but were not included in the questionnaire. The skills identified were: how/when to use software models, how to perform data collection, and understanding the technical aspects of a weapon system program. Though these skills are important they were not included in the selection process for the following reasons. First, the GCA curriculum already includes a four credit hour class on software estimating. This class provides the student with a detailed background of all software models available and their applicability. Additionally, the class has several software estimating cases where the students must run the different software models and compare and contrast the model results. Second, data collection is an area which is extremely difficult to simulate in the classroom setting. The process of data collection varies significantly depending on the estimating environment. Specifically, it is difficult to interpret data without having the personal insights of the experts who were involved in the program under study. Additionally, data collection is already practiced in the GCA program's two regression classes. Moreover, the AFIT thesis program requires most students to practice data collection in support of their research. While data collection is an important skill, it is one which is best developed through experience. Finally, learning the technical aspects of the program is an important aspect of cost estimating, but one that is also difficult to simulate. Providing a plethora of technical information would not add to the validity of the case, and may even detract from the case. As discussed in Chapter II, an exceedingly difficult case only frustrates the student. This is another skill that perhaps is best learned through experience in the program office environment.

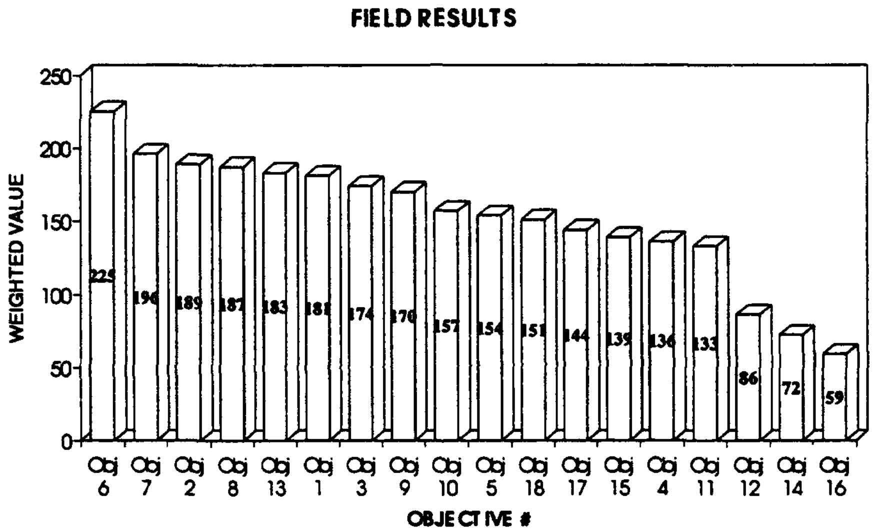


FIGURE 1
Composite Scoring of Objectives

TABLE 4
Description of Objectives

#6 Cross-check	#1 Document preparation	#18 CARD elements *	#12 OGC costs *
#7 WBS	#3 Data normalization	#17 Wrap rates	#14 Briefings
#2 Spreadsheet automation	#9 Analogy estimate	#15 Budget vs cost *	#16 Initial spares *
#8 Parametric estimating	#10 Grass roots estimate	#4 Time phasing	
#13 Risk analysis	#5 C/SCSC	#11 O&S estimate *	

* Recall that these objectives contain several sub-tasks, as presented in Appendix C.

All the identified skills were compared to the skills listed in the draft SAF/FMP report as a cross-check of skill validity. All of the objectives identified in the questionnaire were in fact present in the SAF/FMP report. Thus the SAF/FMP report did not suggest elimination of any skills identified in the questionnaire.

The last step involved taking the questionnaire results and determining which specific skills should be included in the cases. As discussed in Chapter III, the top 50% (nine skills) were selected to form the minimum number of skills to be addressed in the cases. Note that risk analysis (ranked number five) and grassroots estimating (ranked number nine) were not selected. The GCA curriculum already has a class dedicated solely to risk (which includes a case problem). Therefore, risk analysis was eliminated from the list of skills to implement. Grassroots estimating was eliminated due to the exorbitant amount of supporting data required to execute this methodology. After eliminating risk and grassroots, 16 objectives remained. The top 50% (eight skills) were selected. The remaining skills were used in the cases if it was convenient to include them. For example, time-phasing techniques (spread of dollars over the life of a program) is easily implemented, and thus was included in more than one case. Of the sixteen skills only five were not included in any of the cases--indicated by asterisks in Table 4. Final learning objectives for each case were developed from the tasks and are presented in the teaching plans displayed later in this chapter.

Weapon System Program Selection

As stated previously, this effort included two research steps: 1) solicitation of leads on potential weapon system scenarios from the product centers and the AFCAA, and 2) personal interviews of experienced cost analysis personnel.

Solicitation of Product Centers and AFCAA. The questionnaire which formed the basis for this solicitation proved to be unfruitful. Specifically, none of the organizations surveyed provided input on potential scenarios to use in the cases. As a result, alternative sources of estimating scenarios were investigated.

Personal Interviews with Experienced Cost Analysis Personnel. Personal interviews proved to be highly effective in identifying candidate scenarios. Mr John Allen and Captain Tom Tracht identified several potential weapon system programs for use in the cases. These potential programs were then researched at the ASC Cost Library to determine if the scenarios met the criteria stated in Chapter III. Table 5 summarizes the results of the analysis of the various programs. Using Table 5, three weapon system programs were selected for use in the cost estimating cases: LANTIRN (Low-Altitude Navigation Targeting Infrared for Night), C-17, and SBWAS (Space Based Wide Area Surveillance). The LANTIRN program was selected primarily due to the availability of extensive cost estimating documentation found in the ASC Cost Library. Additionally, the cost estimating methodology used in the documentation allowed for the tailoring of the estimating environment. Specifically, an Independent Cost Analysis (ICA) using an analogous methodology was performed on the LANTIRN system by a DoD contractor. This made it relatively easy to modify the scenario to occur at the Air Force Cost Analysis Agency (AFCAA), where the accomplishment of all Air Force ICAs (recently replaced by the term Component Cost Analysis) now takes place.

The second program selected, the C-17, was also chosen primarily due to the extensive amount of cost estimating documentation available. Additionally, since the first case was to involve the AFCAA, it was logical for another case to include ASC to provide adequate diversity in the estimating environments. Moreover, one of the authors of this research effort had cost estimating experience in the C-17 SPO, thereby providing an opportunity to inject case realism into the scenario based on first-hand experience.

TABLE 5
Summary of Weapon System Program Analysis

PROGRAM	DATA AVAILABILITY	PROGRAM PHASE	ESTIMATING ENVIRONMENT	AGE OF PROGRAM
F-22	Data classified	EMD	ASC Aircraft	Initiated in 1980s On-going
LANTIRN	Data extensive and available in cost library and local SPO	O&S	ASC Electronic warfare	Initiated in 1970s On-going
B-1B	Limited data	O&S	ASC Aircraft	Initiated in 1980s On-going
C-17	Data extensive and available in cost library and local SPO	Production	ASC and AFCAA Aircraft	Initiated in 1981 On-going
B-2	Data classified	Production	ASC and AFCAA Aircraft	Initiated in 1980s On-going
F-16	Limited data	O&S	ASC Aircraft	Initiated in 1970s On-going
F-15	Limited data	O&S	ASC Aircraft	Initiated in 1970s On-going
ACM	Limited data	O&S	ASC Missile	Initiated in 1980s Canceled
SBWAS	Data extensive and available at SMC SPO	DEM/VAL	SMC Satellite	Initiated in 1980s Canceled in 1990

Finally, the SBWAS program was chosen due to its ability to offer a third unique estimating environment--space system cost estimating. Additionally, Captain Tracht had previous experience with this specific estimate and was available to provide insight as needed to aid in the development of this case. It should also be noted that the three programs selected all represent different weapon systems--electronic warfare, aircraft, and satellite, respectively--thus providing highly diverse estimating environments for the students.

Case Writing and Implementation

This phase of the analysis involved developing teaching plans, narrative cases, and solutions. Additionally, each case was analyzed based on criteria described in chapter III to measure the overall effectiveness of the case: clarity, realism, difficulty, and student learning. Provided below is a summary of this analysis for each case. Specifically, the title of each case is presented, followed by: the case teaching plan, case clarity analysis, case realism analysis, case difficulty analysis, and student learning assessment. The learning objectives for each case can be traced back to the description of objectives presented in Table 4 by noting the *objective numbers* presented in parentheses at the beginning of each teaching plan.

As described previously, case clarity was evaluated based on feedback from two students who were asked to review each case (different students were selected for each case). The results of the analysis of case clarity is summarized in tables 6, 9 and 12.

Case realism was evaluated based on feedback from the various cost organizations surveyed (SMC, ASC, ESC, AFMC, and AFCAA). The results of this analysis is presented in the form of a descriptive meta-matrix for each case. The first column in each meta-matrix, titled *realism*, identifies the impression each organization communicated in the questionnaire concerning the overall realism of the case. The remaining columns in each meta-matrix refer to specific areas addressed in the questionnaire. Note that feedback suggesting no changes be made was not included in this summary. Only those comments necessitating changes or that confirmed that the objective of realism was met were included. Case realism is summarized in the meta-matrices presented in Tables 7, 10, and 13.

Case difficulty was analyzed using the student feedback questionnaires and comparing the students' perception versus the authors' forecasted rating of difficulty. There were two quantitative measures used to indicate case difficulty--time expended and student perception of case complexity. If the student spent an extreme amount of time on a case it could indicate that the case was too difficult for that particular student. On the other hand, if the person took only a few hours on a case this might indicate the case was too simple. The student's time spent was checked against the student's solution to determine if the student knew what they were doing or if the student exerted little effort in performing the case. The second measure, student perception of complexity, was evaluated by specifically asking the students to rank case complexity on a scale from 1 to 5. The ratings were as follows: 1- not complex, 2- slightly complex, 3- reasonably complex, 4- considerably complex and 5- extremely complex. Figures 2, 3, and 4 summarize the time students spent working on the cases.

Student learning was assessed by analyzing the solutions prepared by the students in the GCA seminar class. This evaluation focused on three areas: methodology, accuracy, and documentation. Again, summary tables (Tables 8, 11 and 14) were used to present the overall assessment of student learning.

LANTIRN Case. Data for this case was extracted from a 1981 analogous estimate prepared by The Analytical Sciences Corporation (TASC) (22). A copy of the LANTIRN case is provided in Appendix I. Solutions are controlled by the GCA program manager.

Teaching Plan. Provided below is the teaching plan for the LANTIRN case.

I. Learning Objectives (*objectives number*: 9, 3, 7, 2, 1):

This case introduces the student to the cost estimating environment in the Engineering and Manufacturing Development (EMD) phase. The student will estimate the EMD and Production portions of a Life Cycle Cost (LCC) estimate.

A. The student should develop an appreciation for the Air Force Cost Analysis Agency estimating environment.

B. The student should apply the analogy method in developing a cost estimate.
1. The student will have to justify the selection of an appropriate analogy.

C. The student should be able to apply techniques to normalize data for differences in complexity and price levels.

1. The student should understand how complexity factors are derived.

2. The student should be able to apply complexity factors to the analogous system.

3. The student should understand the difference between Base Year (BY$), Then Year (TY$), and Current Year (CY$) dollars, and be able to use given inflation indices to inflate and deflate the data.

D. The student should be able to apply cost improvement curves to calculate T1s, slopes, and estimate future lots.

E. The student should understand the purpose of the Work Breakdown Structure.

F. The student should be able to prepare abbreviated cost estimate documentation.

G. The student should be able to create an automated spreadsheet package to construct a weapon system summary (AF Form 1537) in Base Year, Then Year, and Current Year dollars.

II. Student Effort

A. Estimated time out of class: 8 - 10 hours.

B. Resources Available to Student: LEARN, Spreadsheets (QPRO, EXCEL).

C. Group Organization: Cases are designed for groups of two.

III. Teaching Suggestions

A. Subjects that should be addressed, along with proposed times and possible sources of information are listed below.

1. Discuss Air Force Materiel Command (AFMC) structure - the various jobs, product centers, logistic centers, and the Cost Analysis Agency.

- Include a discussion of the overall CCA process and the timing associated with their completion.

SESSION	TIME	SOURCE OF INFORMATION
1	45 Min	Cost Analysis Agency and AFMC Handouts

Suggestion - invite a guest speaker from the AFMC/FM staff to speak to the class on the new AFMC/FM structure

2. Show examples of WBSs and how they are built.

- Show how WBS elements add up to the total weapon system cost.
- Explain the difference between Contractor Furnished Equipment and Government Furnished Equipment, and their impact on the estimate.

SESSION	TIME	SOURCE OF INFORMATION
1	15 Min	Examples from different Product Centers

3. Demonstrate an abbreviated format for documentation.

SESSION	TIME	SOURCE OF INFORMATION
1	15 Min	Examples from different estimates

4. Discuss the use of analogous methods. Discuss the possible criteria for choosing one program over another (judgment, prior contractor, technology, and weapon system specifications). Show examples of the following:

- Choosing one program over another program.
- Averaging two analogous programs for one estimate.
- Taking a percentage of two different analogies (60%/40%).
- Discuss the usefulness of analogous estimating in the various acquisition phases.
- Demonstrate an analogous estimating process.

SESSION	TIME	SOURCE OF INFORMATION
2	1.5 Hours	AFSC Cost Handbook, Blue Book documentation, QMT 550/551 classes.

5. Teach normalization techniques including:

- What are complexity factors.
- Examples of different complexity factors (engineering, manufacturing).
- How complexity factors are used.
- Inflation rates and the difference between BY$, TY$, CY$; plus the different colors of money and how they correspond to the different life cycle phases.

SESSION	TIME	SOURCE OF INFORMATION
3	1.5 Hours	QMT 175, AFSC Cost Handbook

6. Review Cost Improvement Curves and explain how to use the LEARN program.

- Emphasize calculating T1 and slopes from a given data set.
- Demonstrate how to calculate future lots.

- Discuss the different learning curve programs available (ICPRO, LEARN).

SESSION	TIME	SOURCE OF INFORMATION
4	1.5 Hours	QMT 180, LEARN Manual

Case Clarity. As described previously, case clarity was evaluated based on feedback from two students in the GCA curriculum who were asked to review the case. Table 6 summarizes the feedback from the students.

TABLE 6
Summary of LANTIRN Case Clarity

[illegible]	SCENARIO	BACKGROUND	TASKING	GROUNDRULES	METHODOLOGY
STUDENT 1	Clear	Target designator definition unclear	Clear	Analogous system buy schedule unclear	Liked analogous estimate flow chart
STUDENT 2	Informative	Clear	Clear	Unclear on difference between non-recurring and recurring costs	Clear

Based on the above feedback, changes were made to the text of the case or to the student teaching plan to clarify those areas that were previously unclear to the students.

Case Realism. It should be noted that ESC did not submit feedback on the LANTIRN case. Table 7 is a descriptive meta-matrix that summarizes the feedback from the various organizations.

Table 7
Summary of LANTIRN Case Realism

[illegible]	SCENARIO [illegible]	BACKGROUND [illegible]	GROUND RULES	ACQUISITION APPROACH	TASKING	[illegible]
<u>HIGH</u> ASC <u>MODERATE</u> AFMC AFCAA <u>LOW</u> SMC	- CCA suspense unrealistically short (2) - CCA suspense realistic - Scenario realistic (2) - SAF/FMC directs CCA, not PEO	- Good (2)	- State that factors and learning curves were validated	- Good (2)	- Specify learning curve program to use - Address data collection (2)	- Show how complexity factors are developed - Flow chart good - Good materials

* Comments occurring more than once have numbers appended.

The following changes were made to the LANTIRN case based on the realism questionnaire:

1) CCA initiation changed to be directed by SAF/FMC.

2) Added ground rule stating that factors and learning curves were validated by an independent technical assessment team.

3) Added ground rule specifying particular learning curve program.

4) An explanation of the overall CCA process and associated timing was added to the teaching plan.

<u>Case Difficulty</u>. The LANTIRN case was assessed by the authors to be reasonably complex. The amount of time to be spent by the students was estimated to be 8-10 hours. Note that 11 (out of 15) students responded to the questionnaire. The hours spent by the students is shown in Figure 2. The median score for the LANTIRN case is seven hours. The hours spent fell below the range of what was expected. However, the range of time spent was from 5-12 hours, indicating some students had few problems with the case while others may have had much more difficulty. The student's perceived the case to be *reasonably complex*

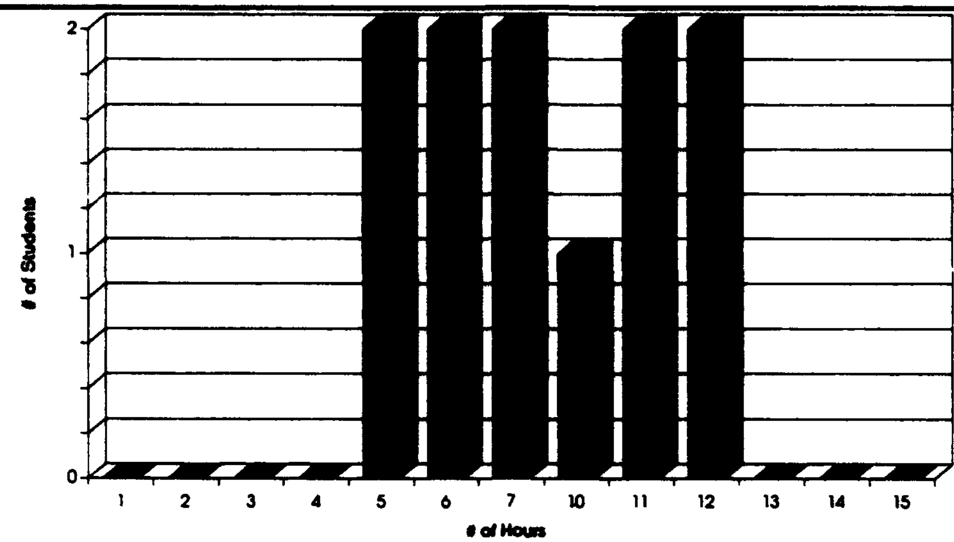


FIGURE 2
LANTIRN Student Hours Expended

which fell right in line with the authors' expectations. The range of complexity varied from 1 to 5, which corresponds with the range of hours spent on the case. The student who took only five hours also ranked the case *not complex*. The LANTIRN case can be made more difficult by removing the flowchart for the analogy process from the content of the case. This step-by-step chart takes the student through the entire analogy estimate. By removing the process flowchart the student must decide on their own how an analogy estimate is built. The problem with deterring the right amount of difficulty needed in a case is not knowing what type of students will be involved. If the whole class has estimating experience this case may be too simple and an adjustment (as mentioned above) to the case may be needed.

Student Learning. Table 8 summarizes how the students performed in each of the areas evaluated for the LANTIRN case.

TABLE 8
Summary of LANTIRN Case Student Learning

METHODOLOGY	ACCURACY	DOCUMENTATION
- Chose PAVE TACK for analogy estimate (5) - Chose Sharpshooter for analogy estimate (1) - Chose to average (equal weighting) PAVE TACK and Sharpshooter for analogy estimate (1) - Used a % factor against the EMD dollar for underestimating due to use of weighted least squares - the % amount is questionable (1) - Derived complexity factors correctly (5) - Properly normalized data (7) - Misapplied learning curve theory(1) - Used a step-down in learning curve, but did not justify (1) -Did not properly weight complexity factors (2)	- Applied wrong inflation indices (1) - Computational errors on 1537s (2) - Error Free (3)	- Choppy documentation (1) - Non replicable estimate (2) - Good documentation, replicable estimate (4) - Did not sum total cost element (1)

There were no major problems with the student solutions, suggesting that the students obtained a reasonable understanding of the estimating concepts introduced in the case.

C-17 CASE. Data for this case was extracted from the 1986 C-17 program office Bluebook documentation (23) and the 1988 C-17 Independent Cost Analysis (24). A copy of the C-17 case is provided in Appendix J. Solutions are controlled by the GCA program manager.

Teaching Plan. Provided below is the teaching plan developed for the C-17 case.

I. Learning Objectives (*Objectives number* 5, 6, 3, 2, 17, 1, 14):

This case introduces the student to the cost estimating environment in the Production phase. The student will estimate the EMD and Production portions of a Life Cycle Cost (LCC) estimate.

A. The student will develop an appreciation for cost estimating in the System Program Office (SPO) environment.

B. The student should be able to comprehend Cost Performance Reports and perform associated calculations.

1. The student will have to calculate the general measures of Estimate at Complete (EAC), Cost and Schedule Performance Indices, and percent complete.

2. The student should be able to apply fiscal year spread (percentages) to their calculated EAC to develop an EMD hours estimate.

3. The student will be able to use cost improvement curves to apply the EMD T1 (based on the above EAC) to their production estimate.

C. The student should apply an appropriate methodology to perform a cross-check of their EAC estimate.

D. The student will understand when and how to apply cost improvement curves with a rate adjustment.

1. The student will understand the different parameters involved in the Learning with rate formulation, and know when it should be applied.

2. The student will understand how the T1s and slopes are affected by the quantity rate adjustment.

E. The student will apply wrap rates to "hour" estimates.

F. The student should be able to prepare abbreviated cost estimate documentation to support their estimating effort.

G. The student should be able to orally defend a cost estimate in a simulated milestone review.

II. Student Effort

A. Time out of class: 13 - 15 hours.

B. Resources Available to Student: LEARN, Spreadsheets (QPRO, EXCEL).

C. Group Organization: Cases are designed for groups of two.

III. Teaching Suggestions

A. Subjects that should be addressed, along with proposed times and possible sources of information are listed below.

1. Discuss the SPO structure and how the Program Control Office fits in. Also discuss the different activities involved in a Program Control Shop.

SESSION	TIME	SOURCE OF INFORMATION
1	20 Min	AFSC Cost Handbook and Info from SPOs

2. Briefly review the Basic C/SCSC calculations. Furthermore, teach the students how to read and interpret Cost Performance Reports.
   - Show examples of Report 22s and 42s.

SESSION	TIME	SOURCE OF INFORMATION
1	30 Min	SYS 362/363, AFSC Cost Handbook, Examples from SPOs

3. Teach students the milestone briefing review process (who the major players are, the cost estimator's role, and the various review boards).
   - Address the major elements that should go into a milestone briefing.

SESSION	TIME	SOURCE OF INFORMATION
1	30 min	AFSC cost handbook

4. Teach the concepts of learning curve with the rate adjustment.
   - Teach the theory and basic calculations.
   - Discuss how learning with the rate adjustment can be incorporated into an electronic spreadsheet.

SESSION	TIME	SOURCE OF INFORMATION
2&3	3 Hrs	Articles, C-17 case rate application guidance

5. Discuss the different approaches to cross-checks and show examples from cost estimates.

SESSION	TIME	SOURCE OF INFORMATION
4	1 Hr	Examples from estimates (F-22)

6. Teach the construction of wrap rates.
   - Define the elements that make up wrap rates (Indirect/Direct labor, profit, G&A, FPRA...)
   - Demonstrate how rates are applied to hour estimates.

SESSION	TIME	SOURCE OF INFORMATION
5	1.5 Hours	Example rate proposals, AFSC Cost Handbook

Suggestion: Have guest speaker who has constructed wrap rates speak to class.

Case Clarity. Table 9 presents the result of the clarity analysis for the C-17 case. Note that ground rules were not separately listed in this case--rather they were embedded in the case narrative. Thus ground rules were not included in any of the feedback evaluations of this case.

TABLE 9
Summary of C-17 Case Clarity

	SCENARIO	BACKGROUND	TASKING	METHODOLOGY
STUDENT 1	Very good, realistic	Clear	Unclear on cross-check	Clear
STUDENT 2	Clear	Clear	Clear	Unclear on cross-check

Case Realism. Feedback on this case was not submitted by SMC. Table 10 summarizes the results of the realism analysis.

TABLE 10
Summary of C-17 Case Realism

REALISM	SCENARIO	BACKGROUND	ACQUISITION APPROACH	TASKING	[illegible]
<u>HIGH</u> AFMC ASC <u>MODERATE</u> ESC AFCAA	- Realistic (3) - Excellent overall case (2)	- Realistic - Need better discussion of rate theory	- Specify whether the EAC formula should be cumulative	- Very good - Data collection oversimplified - Need to verify manufacturing data	- Good

* Comments occurring more than once have numbers appended.

The following changes were made to the C-17 case based on the realism feedback:

1) Rate theory was revised to reflect more accurate discussion of theory.

2) The EAC formula was specified as cumulative.

3) The C-17 narrative was clarified to provide a more accurate discussion of rate theory in cost improvement curve applications.

4) A statement was added to the narrative stating that the C-17 manufacturing hours were developed and validated by another analyst.

<u>Case Difficulty</u>. The C-17 case was evaluated by the authors to be considerably complex. The amount of time to be spent by the students was estimated to be 13-15 hours. Note that only ten (out of 15) students responded to the questionnaire. The distribution of expended student time on the C-17 case is provided in Figure 3. The hours spent fell at the top of the range of what was expected. The range of responses was from 10-18 hours, indicating that for the majority of students with no cost estimating experience some additional instructional guidance may be needed. The median complexity rating *(considerably complex)* mirrored the hours spent by the students and the authors' expectations. The range of complexity varied from 3-5.

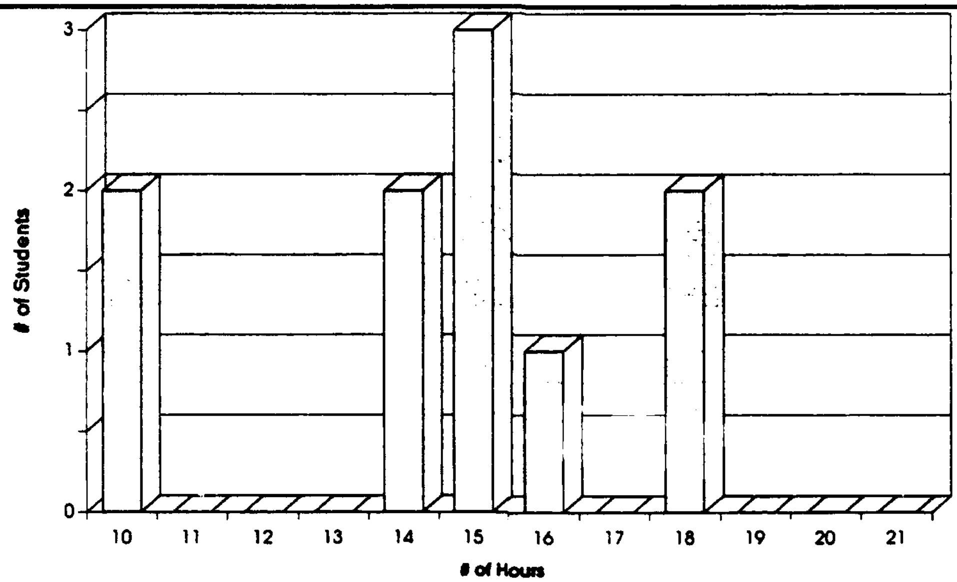


FIGURE 3
C-17 Student Hours Expended

Student Learning. Table 11 summarizes the student learning analysis for this case.

TABLE 11
Summary of C-17 Case Student Learning

METHODOLOGY	ACCURACY	DOCUMENTATION
EMD - performed correctly (7) PRODUCTION - performed correctly (5) - misapplied learning (2) CROSS-CHECK - logically developed (7)	- Underestimated EMD (2) - Overestimated production (2)	- Replicable documentation (7)

There were no major problems with the student solutions. In fact, several of the students presented innovative cross-check methodologies in their documentation and estimate briefing. The considerable difficulty students encountered in conducting this case was not reflected in the solutions they presented. Perhaps their extensive effort (demonstrated by the significant hours spent on the case) overcame any initial problems they had with the case concepts. In any event, the solutions demonstrated an understanding of the learning objectives.

SBWAS Case. Data for this case was extracted from the 1988 SBWAS program office Bluebook documentation (25). A copy of the SBWAS case is provided in Appendix K. Solutions are controlled by the GCA program manager.

Teaching Plan. The teaching plan for this case is provided below.

I. Learning Objectives (*Objectives number* 7, 4, 8, 3, 1, 2):

This case introduces the student to cost estimating in the Concept Exploration phase. The student will estimate the RDT&E and Production portions of a Life Cycle Cost (LCC) estimate.

A. The student will develop an appreciation for cost estimating as a staff cost analyst at the Space & Missile Systems Center.

B. The student will apply the Automated Cost Estimating Integrated Tools (ACE-IT) software program to perform the following tasks:

1. Build a Work Breakdown Structure.
2. Select and execute appropriate CER based methodologies.
3. Incorporate fee, G&A, and overhead in a cost estimate.
4. Perform sensitivity analysis of changes to various system parameters.
5. Time-phase an estimate using an appropriate phasing technique (Beta, man-hour spread etc.,).
6. Develop appropriate cost estimate documentation

C. The student should be able to develop a demonstration/validation cost estimate given various throughputs (technology, contract costs, mission support, etc.,).

II. Student Effort

A. Time out of class: 10-12 hours.

B. Resources Available to Student: ACE-IT Program, Spreadsheets (QPRO, EXCEL).

C. Group Organization: Cases are designed for groups of two.

III. Teaching Suggestions

A. Subjects that should be addressed, along with proposed times and possible sources of information are listed below.

1. Discuss the structure of the Cost Directorate in the Space and Missile Systems Center (SMC).

SESSION	TIME	SOURCE OF INFORMATION
1	15 Min	Dave Hansen slides, LA POCs

2. Review various time-phasing techniques.
   - Include Beta phasing and mahout spreads.

SESSION	TIME	SOURCE OF INFORMATION
1	30 Min	AFSC Handbook

3. Explain the use of multiplicative correction factors (bias reduction factors).

SESSION	TIME	SOURCE OF INFORMATION
1	30 Min	Danneman article and other readings

3. Teach the students how to use ACE-IT and discuss its various functions.
   - In a classroom setting discuss the purpose/background of ACE-IT
   - In a computer lab demonstrate the basic functions of ACE-IT.
   - Specifically address the use of "what-if" analyses.
   - Include a discussion of other automated cost estimating software (such as the ASC cost workstation).

SESSION	TIME	SOURCE OF INFORMATION
2-5	6 Hrs	Tecolote representative

4. Expose the student to various styles of cost estimate documentation.

SESSION	TIME	SOURCE OF INFORMATION
6	45 min	Examples from bluebooks

Case Clarity. Table 12 summarizes the results of the clarity analysis for this case.

TABLE 12
Summary of SBWAS Case Clarity

	SCENARIO	BACKGROUND	TASKING	GROUNDRULES	METHODOLOGY
STUDENT 1	Clear	Outstanding	Very good	Clarify beta curves	Unclear on ACEIT
STUDENT 2	Good	Include overall WBS	Clarify extent of documentation	Clarify beta curves	Unclear on ACEIT

Changes were made to the narrative of this case or the teaching plan based on the above comments. For example, the case tasking was modified to specify that only appropriate documentation should be provided. In other words, students should not submit all of the documentation possible using ACEIT, only that portion which adequately presents the results of the estimating effort.

Case Realism. Note that feedback on this case was not provided by SMC. The descriptive meta-matrix presented in Table 13 summarizes the results of the realism analysis.

TABLE 13
Summary of SBWAS Case Realism

REALISM	SCENARIO	BACKGROUND	GROUND RULES	ACQUISITION APPROACH	TASKING	SUPPORT MATERIALS
HIGH AFMC ASC MODERATE ESC AFCAA	- Very good (2) - Explain that numerous concepts can be explored - Excellent case	- Good section	- Good - State that learning curves were validated - Add contract estimate to this section	- Show where the 5% ECO came from	- Introduce ASC cost workstation (2) - Clarify documentation required - Discuss model verification (2)	- Include discussion of ACEIT model - WBS not compliant with regulations (3)

* Comments occurring more than once have numbers appended.

The following changes were made to the SBWAS case based on the feedback:

1) A ground rule specifying that the two DEM/VAL contractor estimates are judged to be equal in effort was added.

2) The scenario was revised to reflect that numerous concepts were still under exploration, but only one was to be considered in this analysis.

3) A discussion of other automated cost estimating software (such as the ASC cost workstation) was added to the teaching plan.

Case Difficulty. The SBWAS case was evaluated by the author's to be reasonably complex. The median amount of time to be spent by the students was forecasted to be 10-12 hours. Note that only seven (out of 15) students responded to the questionnaire. Figure 4 shows the student time expended for the SBWAS case.

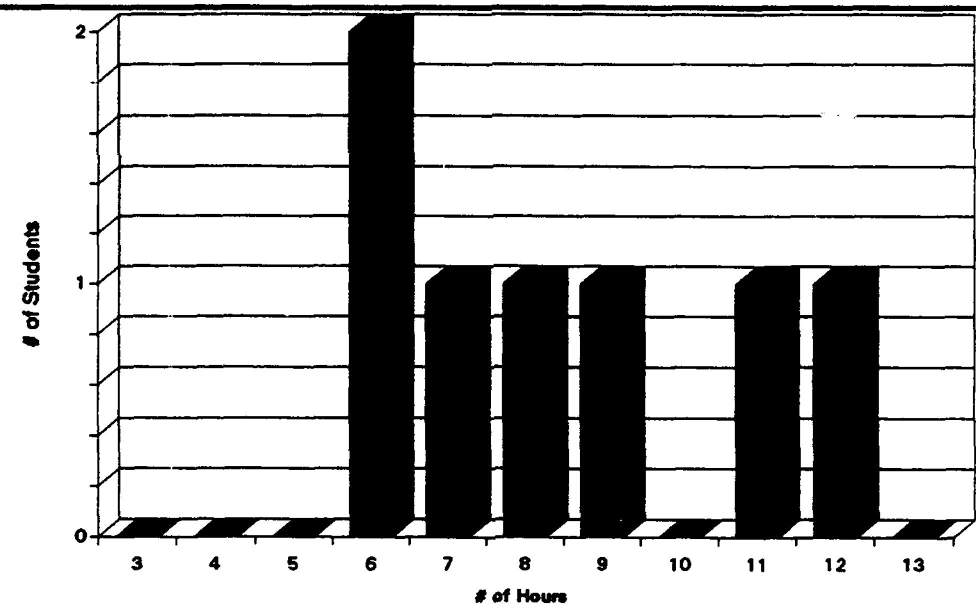


FIGURE 4
SBWAS Student Hours Expended

The median hours (8) spent fell below the forecasted range of the authors. The range of time was from 6-12 hours. At first glance the hours indicate very few students had problems with the case and probably thought the case was simple. However, the solution turned in by most students was of poor quality (the specific analysis of student learning will be covered in the next section). It was difficult to assess the difficulty solely on the hours spent due to the apparent lack of student effort. On the other hand, the overall complexity was right in line with the author's expectations. The range of complexity varied from 2-4. Most students perceived the case to be reasonably complex. However, after looking at the solutions it appeared that many of the students still do not understand how to use ACE-IT. Learning to use the ACE-IT program appeared to be an easy task, but many of the inexperienced analysts mis-applied ACE-IT, and did not realize there mistakes because of their lack of understanding of electronic spreadsheets. Most of the difficulty in this case can be traced to students' inability to use ACE-IT properly; therefore, a good training session for the students is needed for the case to be reasonably difficult.

Student Learning. Table 14 summarizes the student learning evaluation.

TABLE 14
Summary of SBWAS Case Student Learning

METHODOLOGY	ACCURACY	DOCUMENTATION
DEM/VAL - performed correctly (4) - phased wrong (2) - Left out one contractor EMD - performed correctly (6) - misinterpreted CER units PRODUCTION - performed correctly (6) - summary costs omitted	- Overestimated EMD (3) - Overestimated DEM/VAL (2) - Underestimated DEM/VAL (2)	- Replicable documentation (3) - Summary costs omitted (3) - Poorly organized (4)

Many of the methodologies utilized by the students were not logically developed or justified. The primary reason for the student problems with this case was their lack of understanding of the ACEIT software used to conduct the estimate. Specifically, many students misinterpreted the cost estimating relationships (CERs) embedded in the software. Additionally, few of the students were able to properly organize the ACEIT documentation output. Students require more exposure to ACEIT training to overcome these problems.

V. Conclusions and Recommendations

Conclusions

The goal of this research effort was to develop cases that would *bridge the gap* between the theory and priciples of cost estimating currently taught in the AFIT curriculum and the real world of cost estimating in the acquisition arena. To accomplish this effort four research objectives were investigated. The first three research objectives presented in this study basically served to set the stage for the fourth and final objective: provide cases based on realistic scenarios that will facilitate student learning of important cost estimating skills. In other words, the first three objectives provided the inputs required to carry out the fourth objective. Chapter IV presented the results of the analysis of each of these objectives. However, it is objective four that comprised the bulk of this research effort, and fittingly the success of the overall research effort can be accurately gauged through an analysis of objective four's results.

Recall that objective four was analyzed based on four criteria: clarity, realism, difficulty, and student learning. Questionnaires were used to collect data in order to analyze the first three criteria. While the majority of the responses demonstrated the cases met the above criteria, only by incorporating the feedback from these questionnaires into the narrative cases and/or teaching plans could attainment of this objective be assured. Based on the results presented in Chapter IV, the authors are confident that the three cases presented in the Appendices are in fact clear, realistic, and of appropriate difficulty.

It should be noted that assessing the appropriate level of difficulty of a case is a subjective determination that must be made in light of the skill and experience base of the targeted students. The level of difficulty designed into these cases was constructed to meet the background of the students in the current AFIT GCA curriculum. While it is probable that the skill mix of future GCA students will remain somewhat consonant with this baseline, it is still possible that a future class could have considerably more or less cost estimating experience. The cases were designed to accommodate for this through instructor modifications to either the attachments provided in the cases, or to the teaching plans. For example, the LANTIRN case was designed to be the most straightforward case developed (as substantiated through student feedback). However, this case can be made considerably more difficult simply by removing the *analogy estimate flow chart* given in the case. This would result in students having to make several more decisions in their analysis. Additionally, the C-17 case was designed, and through student feedback was proven to be, the most difficult case. The instructor can make this case less complex by providing examples of estimate cross-checks and discussing the creativity involved with their derivation. A significant driver of difficulty in the SBWAS case involves the software the case requires the student to use--Automated Cost Estimating Integrated Tools (ACEIT). Any attempt to modify the difficulty of this case would require changes to the amount of ACEIT training made available to the students.

The final criteria used to measure the overall effectiveness of the cases--student learning--was analyzed by evaluating the solutions to the cases submitted by the students in the GCA seminar class. Evaluation of the solutions was not based solely on the final *numbers* presented, but primarily on the soundness of the methodology employed by the students. As discussed in Chapter IV, many unique solutions to the cases were presented by the students. The vast majority of these solutions did in fact meet the test of reasonableness. Based on the above discussion, the authors are confident that the cases introduced in the GCA seminar class did in fact facilitate student learning of important cost estimating skills.

Recommendations

The results of this effort have generated the following suggestions for further research efforts.

Recommendation 1. Additional cases should be developed to further integrate the case method of instruction into the GCA curriculum. All 15 of the students in the seminar class communicated through the difficulty questionnaires that the cases were extremely helpful in solidifying their understanding of acquisition cost estimating. In fact, they all agreed that additional cases introduced throughout the curriculum would be even more helpful. Specifically, cases should be developed to address those cost estimating skills identified by the field questionnaires but not included in the cases presented here. For example, a case could be developed to allow students to prepare an operations and support cost estimate.

Recommendation 2. The cases should be introduced earlier in the curriculum to provide students with more time to focus on the cases. Nearly all of the students in the seminar class felt their thesis efforts in the final quarter detracted from their ability to focus on the cases. These students all suggested implementing the cases earlier in the curriculum, such as in the spring quarter.

Recommendation 3. Consider making the cases individual efforts versus being performed in groups of two. A few of the students related that the case taskings were sometimes *split-up* between members of a team, versus being performed together as designed. Thus it is possible that a student may only have been exposed to half of the learning objectives for a particular case. It could be that the workload of the last quarter at AFIT (due to the thesis effort as discussed above) forced a few of the groups to divide their taskings. If the cases are implemented in an earlier quarter next year, two person teams may still be appropriate as students may not feel as much time pressure to get through the cases.

Appendix A:

Partial List of Cost Estimating Terms

Definitions (8:A1-A79)

Acquisition Cost: The sum total of all development and production costs for a program. Acquisition cost plus ownership cost equals total life cycle cost.

Algorithm: A set of ordered procedures, steps, or rules usually applied to mathematical procedures and assumed to lead to the solution of a problem in a finite number of steps.

Analogy: An estimating method that uses actual costs of a similar existing or past program and adjusts for complexity, technical, or physical differences to derive new system estimate. Also referred to as analog and analogous cost estimates.

Analysis: A systematic approach to problem solving. Complex problems are simplified by separating them into more understandable elements.

Base Year Dollars: Dollars which are expressed in the economic condition of a specific year and do not include escalation or inflation for future years. A base year dollar reflects the "purchasing power" of the dollar for the specified base year.

Budgeting: The process of translating approved or negotiated resource requirements (manpower and material) into time-phased financial targets or goals.

Catalog Estimating: An approach, also known as handbook estimating, involving the use of handbooks, catalogs, and other reference books that are published with price lists for standard, off-the-shelf items.

Constant Year Dollars: A phrase reflecting the dollar "purchasing power" for a specified year. An estimate is in constant dollars when prior years costs are adjusted to reflect the level of prices of the base year, and future costs are estimated without inflation.

Contract Work Breakdown Structure (CWBS): The work breakdown structure that addresses only those WBS elements applicable to a specified contract.

Cost Driver: The characteristics of a system or end item that have a large or major effect on the system's cost.

Cost Estimating Relationship (CER): A mathematical expression relating cost as the dependent variable to one or more independent cost driving variables. The relationship may be cost-to-cost such as using manufacturing hours to estimate quality assurance hours or using manufacturing hours to estimate dollars for expendable material such as rivets, primer, or sealant. The relationship may also be cost-to-noncost such as estimating manufacturing hours by the use of weight or using the number of engineering drawings to estimate engineering hours. Both weight and engineering drawings are noncost variables.

Cost Improvement Curve Theory: A theory that states that the quantity of items produced increases, costs decrease at a predictable rate. "Unit" cost improvement curve theory describes the relationship between the cost of individual units. "Cumulative average" theory describes the relationship between the average cost of different quantities of units.

Cost Model: An estimating tool consisting of one or more cost estimating relationships, estimating methodologies, or estimating techniques used to predict the cost of a system or one of its lower level elements.

Cross-Check Method: An estimating methodology that is different from the estimating approach selected as the primary method. It is typically applied to those cost elements that contribute heavily to the total estimate to ensure that the primary method employed has generated credible results.

Discounting: A technique for converting forecasted amounts to economically comparable amounts at a common point in time, considering the time value of money.

Estimate At Completion (EAC): The current estimate of what the final cost will be for the task, whether it be the total contract or just a portion therof. It consists of actual costs t date plus the estimate of the balance to complete through contract completion.

Grass Roots Estimate: (1) Prepared by contractors - an estimate developed by requesting and collecting estimates from functional organizations within a company or agency for a specific statement of work or task. Usually developed by a combination of many estimating methods and techniques but developed by the "doing" people. (2) Prepared by in-house Government Analysts - normally done at a functional level of detail with regards to labor with a breakout of major subcontracts and material items also included. It is normally prepared to forecast out-year costs for systems in production or for which prototype production cost data are available.

Independent Cost Estimates: An analysis of program cost prepared in support of the AFSARC/DAB process, generally accomplished on all major weapon system programs at Milestone I, II, and III. It is intended to provide an independent "test of reasonableness" of the PCE and as such, it is a discrete point estimate prepared by a team organizationally separate from program advocacy.

Inflation: A rise in the general level of prices. Pure inflation is defined as a rise in the general level of prices unaccompanied by a rise in output (productivity).

Major Weapon System: One of a limited number of systems or subsystems which, for reasons of military urgency, criticalness, or resource requirements, is determined by the DoD as being vital to the national interest.

Most Probable Cost (MPC): The Government's estimate for each competing bidder in a source selection environment. MPC results are used by the source selection authority in determining the winning contractor, and it often becomes the only meaningful measure of the realism of the bidders' cost proposal.

Normalized: (1) Data base - to render constant or to adjust for known differences. (2) Dollars - various fiscal year costs are inflated/deflated to a common year basis for comparison.

Operating and Support Costs (O&S): The added or variable costs of personnel, materials, facilities, and other items needed for the peacetime operation, maintenance and support of a system during activation, steady state operation, and disposal.

Overhead: (Indirect) A cost which, because of its incurrence for common or joint objective, is not readily subject to treatment as a direct cost. Such indirect cost is incurred to benefit the total direct cost or business base of a contractor. Accordingly, the overhead applicable to any one estimate or contract is by an appropriate distribution of indirect costs through the use of a rate per hour or percentage applied to direct hours or costs.

Parametric Estimating: An estimating technique which employs one or more cost estimating relationships. It involves collecting relevant historical data at an aggregated level of detail and relating it to the area to be estimated through the use of mathematical techniques.

Program Acquisition Costs: The sum of development and production costs. Military construction costs may be included if directly related to the weapon system. Initial spares are also included.

Program Cost Estimate (PCE): A program manager's official estimate of the financial resources required to competently conduct the program contained in the Program Management Directive.

Regression Analysis: The association of one or more independent variables with a dependent variable. Under static conditions the analysis is called correlation. When used for predictive purposes, it is referred to as regression.

Sensitivity Analysis: Repetition of an analysis with different quantitative values for selected parameters or assumptions for the purpose of comparison with the results of the basic analysis. If a small change in the value of the variable results in a large change in the results, then the results are said to be sensitive to that parameter or assumption.

Statement of Work: A document stating the confines of the contractual work to be accomplished. The part of an RFP or contract that defines the work which a customer wants performed.

Then Year Dollars: Dollars which reflect purchasing power at the time expenditures are actually made. Sometimes referred to as escalated or inflated costs. Prior costs expressed in then year dollars are the actual amounts paid out in these years. Future costs stated in then year dollars are projected actual amounts to be paid.

Weapon System Cost: Flyaway cost plus the elements of peculiar support equipment, data, and training, as well as operational/site activation and industrial facilities. The only production cost excluded in this calculation is that of initial spares.

Work Breakdown Structure (WBS): A method of diagramming the way that work is to accomplished by separating the work content into individual elements.

Wrap Rates: A total rate per hour that covers direct labor, overhead, fringe benefits, and other costs. Also may include factored labor costs, support services, travel, and material costs.

Appendix B:

Description of Cost Analyis Courses in GCA Curriculum

Statistics for Cost Analysts. This course is an introduction to descriptive and inferential statistics. The course covers various measures of central tendency and dispersion, as well as some typical display techniques. The concepts of probability and nonparametric tests are covered in great detail.

Defense Cost Modeling. This course focuses on the use of regression analysis as a methodology for developing cost models. Single and multiple predictor linear models are analyzed, followed by a discussion of non-linear models.

Quantitative Management of Software. Covers the topic of software management with emphasis on quantitative activities such as software estimation and measurement. Other issues addressed include the software development process; software product assurance; and software size, quality, and schedule.

Model Diagnostics. This course is a continuation of Defense Cost Modeling. It explores the problem of developing cost models when one or more of the basic assumptions of the regression model do not hold true.

Life Cycle Cost and Reliability. Explores the concepts and methodologies which should be considered in the development or improvement of the life cycle cost (LCC) models. The different types of LCC models are defined and the limitations of specific models in use are discussed.

Project Risk Analysis. Introduces the concept of risk in the acquisition of major weapon systems. The elements of technical, schedule, and cost estimating risk are discussed, with a specific focus on the different quantitative and qualitative methods of predicting cost risk.

Cost Estimating for Weapon System Production. The purpose of this course is to provide students with the skills needed to analyze data provided by major weapon system contractors. The manufacturing and production process is introduced to the student, with a focus on learning curve theory.

Seminar in Cost Analysis. Introduces the student to current topics and issues of interest to the cost analysis community. Integrates the material covered in the curriculum. This is the targeted location for implementing the cases developed in this research effort.

Appendix C:

Cost Estimating Skills Questionnaire

FROM: AFIT/LAS (Major Simpson) 9 Feb 93

SUBJECT: Case Studies to Support AFIT Cost Analysis Curriculum

TO: Case Study Points-of-Contact
AFCAA/CC (Col Ronald Daigler)
AFMC/FMC (Col Richard Michaud)
SMC/FMC (Mr David Hansen)
ASC/FMC (Mr R.B. Schwenke)
ESC/FMC (Ms Ellan Coakley)

1. Two members of the current Graduate Cost Analysis class are developing a set of student cases to be used in cost analysis curriculum here at AFIT. Capt Kerrie Glenn and Capt Jim Passaro's thesis effort is to provide a set of cases that will develop and test the AFIT student's abilities to apply the concepts taught in the cost analysis curriculum. To ensure that we produce a relevant product, we invite you to participate in the preparation and review of the cases.

2. There are three ways in which you can help us in the case development. First, we would like your input on the objectives that the cases should seek to achieve. The attached document is an informal questionnaire designed to solicit your input on case objectives. Second, we ask you to identify potential data sources that you feel will support the case objectives. We feel the value of the cases will increase if they realistically reflect the characteristics of the different weapon systems we estimate. To the extent that these cases can be grounded in "real-world" systems and "real-world" data, the better the cases will prepare the student. Finally, we ask you to review the cases as they are drafted. We feel the quality of the product can be improved through a review by estimators in the field.

3. Jim and Kerrie would like to complete the cases in time to test them on the current GCA class this summer. In order to accomplish this, they will need to have final drafts by 15 Jun. To support this schedule, we ask that you return your inputs on case objectives as soon as possible. If we receive your inputs by 28 February, we feel that we have a good chance of meeting our schedule.

4. Thank you for your time and cooperation. If you have questions, please contact Capt Kerrie Glenn at (513) 426-0703 or Capt Jim Passaro at (513) 435-2280.

WENDELL P. SIMPSON III, MAJ, USAF
Manager, Graduate Cost Analysis Program

Atch
Cost Analysis Case Questionnaire

AFIT Graduate Cost Analysis Program
Cost Analysis Case Questionnaire

This document gives a brief summary of the background and intent of the cost analysis cases, and proposes a set of draft objectives. In our efforts to improve the GCA program, we continually solicit feedback from GCA graduates, their supervisors and the leadership of the cost community. Recent feedback indicates that we might improve our product if we were to add more opportunities for the students to apply the theory we teach. The cost cases are part of a broader effort to increase the emphasis on application of theory in the GCA curriculum without de-emphasizing our teaching of the theory itself.

Please understand that most of the objectives listed on the attached are already covered somewhere in the curriculum. For example, the curriculum already contains a three course sequence on developing and evaluating parametric cost models. The students generally are exposed to estimating techniques and issues in isolation to allow for in-depth study of the topic. The weakness in the program that we are trying to address with the cases springs from the fact that the objectives are sprinkled throughout the curriculum and students do not have much opportunity to bring them together and "estimate". The purpose of the cases is to provide a vehicle to pull together the objectives and techniques scattered throughout the curriculum and to integrate them into a simulated estimating scenario. We would like your help in identifying those skills that should be included and integrated in the cases.

In addition to integrating concepts already in the curriculum, the cases provide an opportunity for the student to begin developing some skills that are not covered in the curriculum. These are skills that are generally not addressed at the graduate level, but can be important to their success in the cost field. For example, we do not currently include in the curriculum any instruction on how to construct a cost spreadsheet. While the students use spreadsheets to support their course work, they do not have the opportunity to construct a spreadsheet that has many different embedded cost equations and that is well-designed in terms of capability to support "what-if" exercises. (This should remain a valuable skill even as we move towards the "cost workstation concept). A cost estimating case provides a wonderful opportunity to teach some of these skills before they complete the program.

We would like you to review and comment on the objectives as proposed, and to identify any objectives that you feel ought to be added to the list. When you have your proposed list completed, we ask you to prioritize the list based on your experiences and collective opinions.

As points-of-contact for your organization, we encourage you to involve as broad a spectrum of cost analysts as you find practical. Ideally, we would like at least three participants from each organization. If possible, we ask that the participants reflect a range of experience in estimating. We feel it is just as important to consider the opinions of new estimators as it is the opinions of the experienced estimators. In addition, we would appreciate it if some of the participants are GCA graduates. Our purpose is to better equip the GCA students as he or she leaves the program. GCA graduates may offer some unique insights based on their personal experiences after completing the program.

Thank you for participating in our project. We feel that your perspective is essential in creating relevant problem situations in which the students will learn the skills that will be important to them in their future careers.

Kerrie Glenn
Jim Passaro

Use the following to provide some basic data on the participants in the process of developing objectives:

Date: ______________________________

Organization (circle one):

AFCAA AFMC ASC SMC ESC

Participants:

	Grade	Years of Estimating Experience	GCA Graduate (Y or N)
1.)			
2.)			
3.)			
4.)			
5.)			

Please identify any sources of data that you feel may be especially helpful developing the cost cases (ICE or POE documentation, cost studies, cost research reports, etc.)

What spreadsheet software is most commonly used in your organization?

Are you presently using a cost workstation in your organization? If so, which one? Do you plan to adopt a cost workstation in the foreseeable future? Again, which one?

Are there one or two parametric cost models that predominate in your organization? If so, which ones?

Are there one or two learning curve programs that predominate in your organization? If so, which ones?

Please rank the *single-dashed objectives* in terms of the priority you feel the thesis team should assign in the process of creating the cost cases. Use the space at the bottom of the form to identify objectives that you feel should be added to the list along with their priority ranking. (Note: the double-dashed statements are supporting samples of behavior that we might expect of the student if the objective were achieved.)

LEARNING OBJECTIVES:	RANK
- Prepare appropriate cost estimating documentation. --Describe a general format for documentation. --Identify when documentation is required. --Understand the documentation review process.	
- Develop computer spreadsheets to automate weapon system cost estimating. --Use spreadsheets to automate the application of CERs (can include learning curves, and other cost estimating techniques).	
- Utilize normalization techniques. --Understand how engineering/manufacturing complexity factors are developed and used. --Use inflation indices to normalize data. --Define base year, then year and constant year dollars.	
- Understand the various time-phasing techniques (empirical, beta). --Construct a time-phased estimate. --Apply inflation indices to move from base year to then year dollars.	
- Interpret Cost Performance Reports (CPRs). --Define the various CPR performance measurements (BCWP, ACWP, BCWS, EAC).	

LEARNING OBJECTIVES:	RANK
--Calculate the general measures of variance and other appropriate measurement calculations (percent complete, CPI, SPI). --Calculate and differentiate between the various types of EACs.	
- Choose an appropriate methodology and perform a cross-check of a given cost estimate.	
- Understand the purpose and uses of a Work Breakdown Structure.	
- Use a parametric methodology in developing a cost estimate.	
- Use the analogy method in developing a cost estimate.	
- Use a grass roots methodology in developing a cost estimate.	
- Summarize the elements that comprise an O&S cost estimate. --Interpret O&S cost model outputs.	
- Understand the elements that comprise Other Government Costs and their impact on the total weapon system cost estimate.	
- Compute cost risk using a given model.	
- Prepare an estimate briefing for a milestone review. --Explain the concepts of life cycle costs. --Know the differences, in function and form, between a program office estimate and a component cost analysis (CCA). --Understand the program office estimate review process.	
- Compare cost estimates to budget available and develop possible courses of action (what-ifs) to reconcile.	
- Explain the purpose and use of initial spares.	

LEARNING OBJECTIVES:	RANK
- Construct wrap rates --Understand accounting concepts (Overhead, profit, direct charges, indirect labor...). --Understand the use of wrap rates in cost estimates.	
- Know the elements that comprise a Cost Analysis Requirements Description (CARD). --Understand the function of a CARD in the acquisition process.	

Appendix D:

Sample Data Collection Sheet

CASE DATA COLLECTION WORKSHEET

Case Title:____________________

Case Authors:____________________

SECTION	DATA AVAILABLE	DATA REQUIRED
SCENARIO AND ORGANIZATION INFO.		
BACKGROUND OUTLINE		
SPECIFIC AREAS OF INTEREST		
LEARNING OBJECTIVES		
EXHIBIT MATERIAL NEEDED		

Appendix E:

Case Clarity Questionnaire

Dear Case Tester,

Thanks a lot for helping us out. Your insights will be crucial to making the seminar class (which is being built around these cases) a successful learning experience. Please take the time to fully evaluate this case. Provided below are specific questions we need you to answer as fully as possible. If you have any additional comments for us, please don't hold back--your feedback will be incorporated in our final case product. **Thanks again for your help!!**

CASE QUESTIONS

1) Identify anything you would add/change/delete from the "Scenario" section to make it more realistic and interesting. What did you particularly like or dislike about that section?

2) Were your responsibilities in completing this case clearly identified? What would you add/change/delete in the "Organization Background" section to make the overall case a more effective learning tool?

3) Identify any of the "Ground Rules/Assumptions" that were confusing to you. How would you change them to make them more useful? Are there any other assumptions you would add or change?

4) What did you particularly like/dislike about the "System Background" section (including the acquisition approach and target designator descriptions)? Is there any additional information you feel would have been helpful? Identify any information in this section that was confusing to you.

5) Were the attachments/figures helpful? (please explain). What would you add/change to make them more useful?

6) **This question is extremely important.** Briefly outline the estimating methodology you would use to solve this case. Describe what you believe will be the major decision points and the overall flow of your anticipated methodology.

7) If you could add/change/delete anything(s) about this case, what would it be and how would you do it?

8) Estimate how much time you spent conducting your review.

Appendix F:

Case Realism Questionnaire

FROM: Major Wendell Simpson 7 Jun 93
AFIT/LAS
2950 P Street
WPAFB OH 45433-7765

SUBJ: AFIT Cost Analysis Case Evaluations

TO: Mrs Ellen Coakley
ESC/FMC (Technical Director)
9 Eglin Street
Hanscom AFB, MA 01731-2117

1. Earlier this year we invited you to participate in the development of a set of cost analysis cases to be used in the curriculum here at AFIT. We asked you to provide us with your perceptions of the importance of possible objectives for the cases. Based on the responses we received from the field, Captain Kerrie Schieman and Captain Jim Passaro have been developing three cases to address the high priority objectives.

2. Our goal is to produce cost analysis cases that challenge the students and help prepare them to make some of the analytical decisions that will be expected of them in the field. An important step in the process to achieve that goal is to obtain feedback from analysts in the field as to the quality and relevance of the cases. We ask that cost analysts in your organization review the draft cases and complete an evaluation form to communicate their impressions. The first of the draft cases and an evaluation form are attached.

3. In order to incorporate your comments into their thesis and meet our deadlines here, we will need to receive your comments no later than 15 July. The students in the current graduate cost analysis class will be using the cases during the summer quarter beginning 1 July. If we receive your evaluations before the end of June, there is a good chance that we will be able to incorporate your comments before giving the cases to the students.

4. Thank you for your time and cooperation. If you have any questions, please contact Captain Schieman at (513) 426-0703 or Capatin Passaro at (513) 435-2280.

WENDELL P. SIMPSON, MAJ, USAF
Manager, Graduate Cost Analysis Program

2 Atch
1. Draft Case
2. Evaluation Form

Name:______________________________ Date:______________

Office Symbol/Phone:__________________________

CASE 1
CASE EVALUATION QUESTIONS

1. SCENARIO -- How could we make the scenario more realistic and interesting?

2. ORGANIZATION BACKGROUND

   a. How could we change this section to make it more complete, informative and accurate?

   b. How should the "Groundrules and Assumptions" be modified to help clarify the case?

3. SYSTEM BACKGROUND -- Did this section provide an approprite amount of technical information given the estimating scenario?

4. ACQUISITION APPROACH -- Are there any changes that would make this section more accurate and realistic?

5. TASKING -- Did this section clearly identify the student requirements and expectations in the case?

6. SUPPORING MATERIAL -- How can we improve the attachements and figures?

7. OVERALL IMPRESSION -- If you could add, change or delete one thing about this case, what would it be and how would you do it?

Appendix G:

Case Difficulty Questionnaire

CASE CRITIQUE

1. Identify any sources of information (outside the case itself) that you felt were necessary or especially useful in analyzing the case (i.e., specific class presentation, other students, other source).

2. a) List the key decisions you had to make to complete the case.

   b) Which decision was the most difficult for you to resolve?

   c) Was the decision described in "b" above difficult due to:
      1. Case not being clear (specify what was unclear)
      2. Necessary information omitted (be specific)
      3. Did not understand a particular concept (such as...)
      4. Other (please explain)

3. Estimate the total number of hours you spent individually on the case.

4. Try to rate the overall difficulty of the case on the following scale from 1 to 5.

   1. Not complex.
   2. Slightly complex.
   3. Reasonably complex.
   4. Considerably complex.
   5. Extremely complex.

5. Identify any cosmetic changes you recommend for the case (use reverse as needed).

Appendix H:

Spreadsheet Used to Calculate Ranking of Objectives

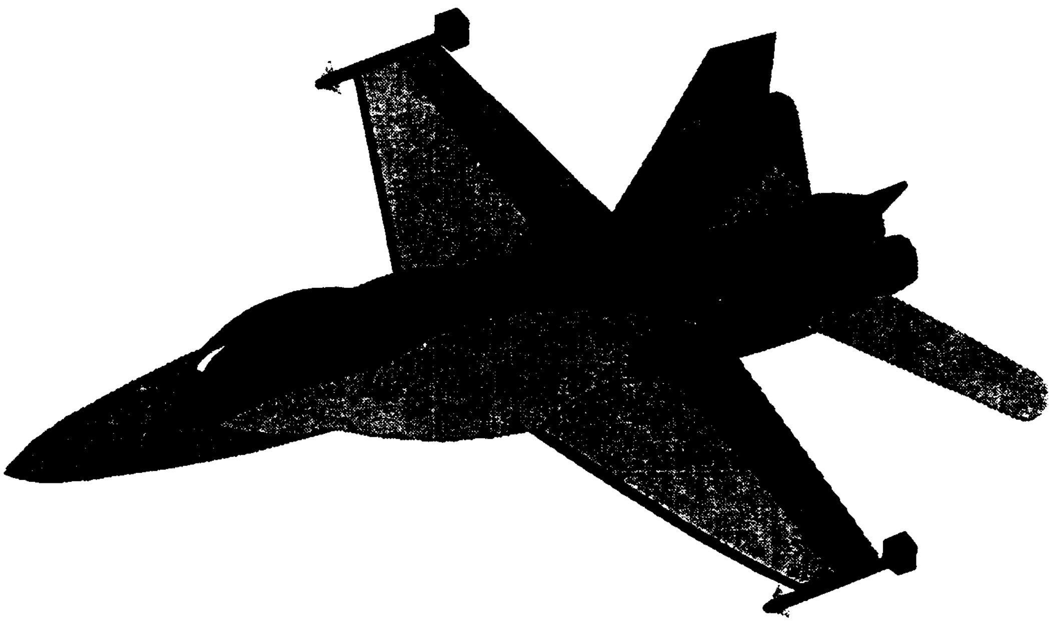
Skills Composite Weightings

	RANKINGS																	
OBJECTIVE #	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Total Points
Obj 6	7	3	0	0	1	0	0	1	0	0	1	0	1	1	1	0	0	0	225
Obj 7	1	3	1	1	1	1	2	1	2	0	0	1	1	0	0	0	0	1	196
Obj 2	2	1	2	0	1	1	2	2	2	0	1	0	0	0	0	0	1	1	189
Obj 8	1	1	3	2	2	1	0	0	0	1	0	1	1	0	2	1	0	0	187
Obj 13	1	1	4	0	1	1	1	1	0	1	1	1	0	1	1	0	0	1	183
Obj 1	1	1	2	1	1	1	1	1	2	0	0	2	1	1	1	0	0	0	181
Obj 3	0	1	0	0	1	3	2	3	3	0	1	0	1	0	0	1	0	0	174
Obj 9	1	1	2	3	1	0	1	0	0	0	1	0	1	2	0	2	1	0	170
Obj 10	2	0	0	2	2	1	0	1	0	0	1	1	1	1	2	1	1	0	157
Obj 5	0	0	0	2	0	2	2	2	0	2	1	0	3	0	2	0	0	0	154
Obj 18	0	1	0	2	1	0	0	2	1	3	1	1	1	1	0	1	1	0	151
Obj 17	0	0	0	1	1	3	1	0	0	2	2	1	1	3	0	0	1	0	144
Obj 15	0	2	2	2	0	0	1	0	0	1	1	0	0	0	0	3	1	3	139
Obj 4	0	0	0	0	0	1	1	1	3	3	0	4	1	1	1	0	0	0	136
Obj 11	0	1	0	0	2	1	2	0	1	1	1	0	1	0	3	1	1	1	133
Obj 12	0	0	0	0	0	0	0	1	1	0	3	1	1	3	1	1	2	2	86
Obj 14	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	2	4	3	72
Obj 16	0	0	0	0	0	0	0	0	0	1	1	2	0	1	1	3	3	4	59
	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	

Appendix I:

LANTIRN Case

LANTIRN COMPONENT COST ANALYSIS (CCA)



Prepared by:
Captain Kerrie G. Schieman
Captain James R. Passaro

SCENARIO

"Guess what Karen, another cost estimate came down the pipe today. As usual, they want it done yesterday. It looks like were gonna be busy for the next few weeks."
Karen Lopez is a member of the Command, Control, Communications, and Intelligence (C^3I) Division at the Air Force Cost Analysis Agency, located in Crystal City, Virginia. Karen's boss, Major Andy Russell, is the C^3I Division Chief. Karen's responsibilities include developing cost estimates for various Air Force C^3I systems in support of acquisition milestone decisions.

Major Russell leaned back in his chair and folded his arms over his chest as he outlined the latest tasking to Karen. "The Electronic Systems Program Executive Officer (PEO) has directed us to provide a component cost analysis (CCA) for the Low Altitude for Night-Time Infrared Navigation (LANTIRN) system. I'm going to count on you to take the lead on this one." "So what's the time frame on this estimate?" Karen asked, her face already beginning to wrinkle in anticipation of the anxiety Major Russell's response might evoke. "Two weeks from today", he replied. "The LANTIRN program office used contractor data and development actuals to develop their program office estimate. Here's all the information I could get my hands on," Major Russell stated, handing over a 6" stack of papers and file folders. Major Russell continued, "I'll get with you this afternoon to go over exactly what I'm expecting on this one." At that point Karen turned and headed back to her desk.

ORGANIZATION BACKGROUND

The Air Force Cost Center was established in 1986 to analyze, estimate, and validate the cost of executing the Air Force's total program. In 1991, it was redesignated the Air Force Cost Analysis Agency (AFCAA). The agency, located in Arlington, Va., near the Pentagon, reports directly to the Assistant Secretary of the Air Force (Financial Management and Comptroller). AFCAA's primary mission is to prepare component cost analyses (CCA), formerly known as Independent Cost Estimates, for major defense acquisition programs required for Air Force Selected Acquisition Review Council (AFSARC), Defense Acquisition Board (DAB), and program reviews. The Cost Agency must also prepare CCAs for automated information systems scheduled for the Major Automated Information Systems Review Committee (MAISARC). The AFCAA also develops cost models, methodologies, and databases necessary to insure credible CCAs and other cost estimates/cost analyses performed throughout the Air Force. AFCAA consists of four weapon system divisions and a program control division. Figure 1 displays an organizational chart of the four weapon system divisions at the Cost Agency.

AIR FORCE COST ANALYSIS AGENCY

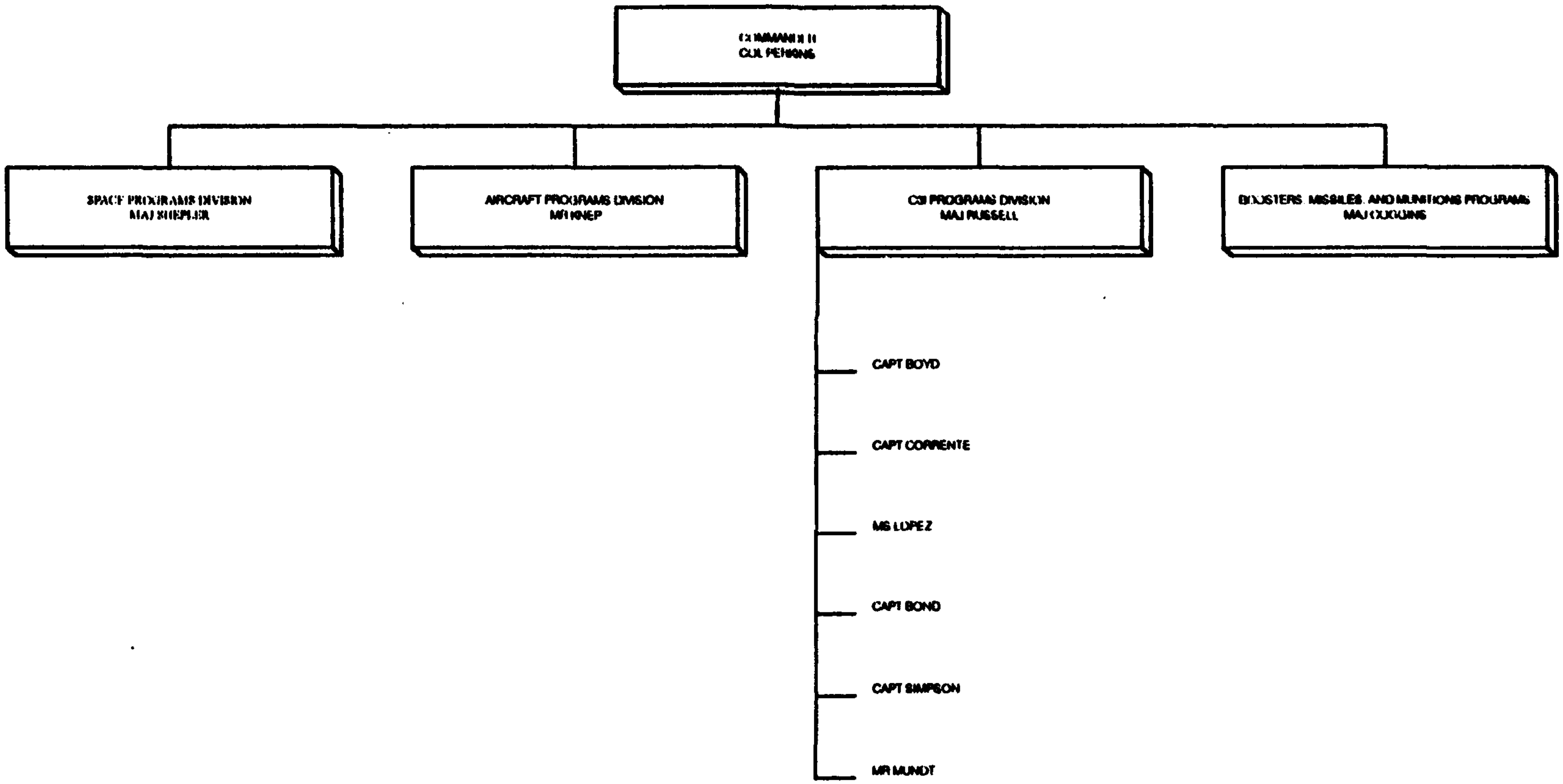


Figure 1

SYSTEM BACKGROUND

The LANTIRN Program was initiated to develop and produce a system to provide Tactical Air Forces with a low-level, day and night, under-the-weather attack capability for high performance single seat aircraft. LANTIRN will provide the means by which close support aircraft can acquire their targets and deliver guided and unguided weapons. The LANTIRN system is presently intended for use on the F-15E, A-10 and the F-16C/D model aircraft.

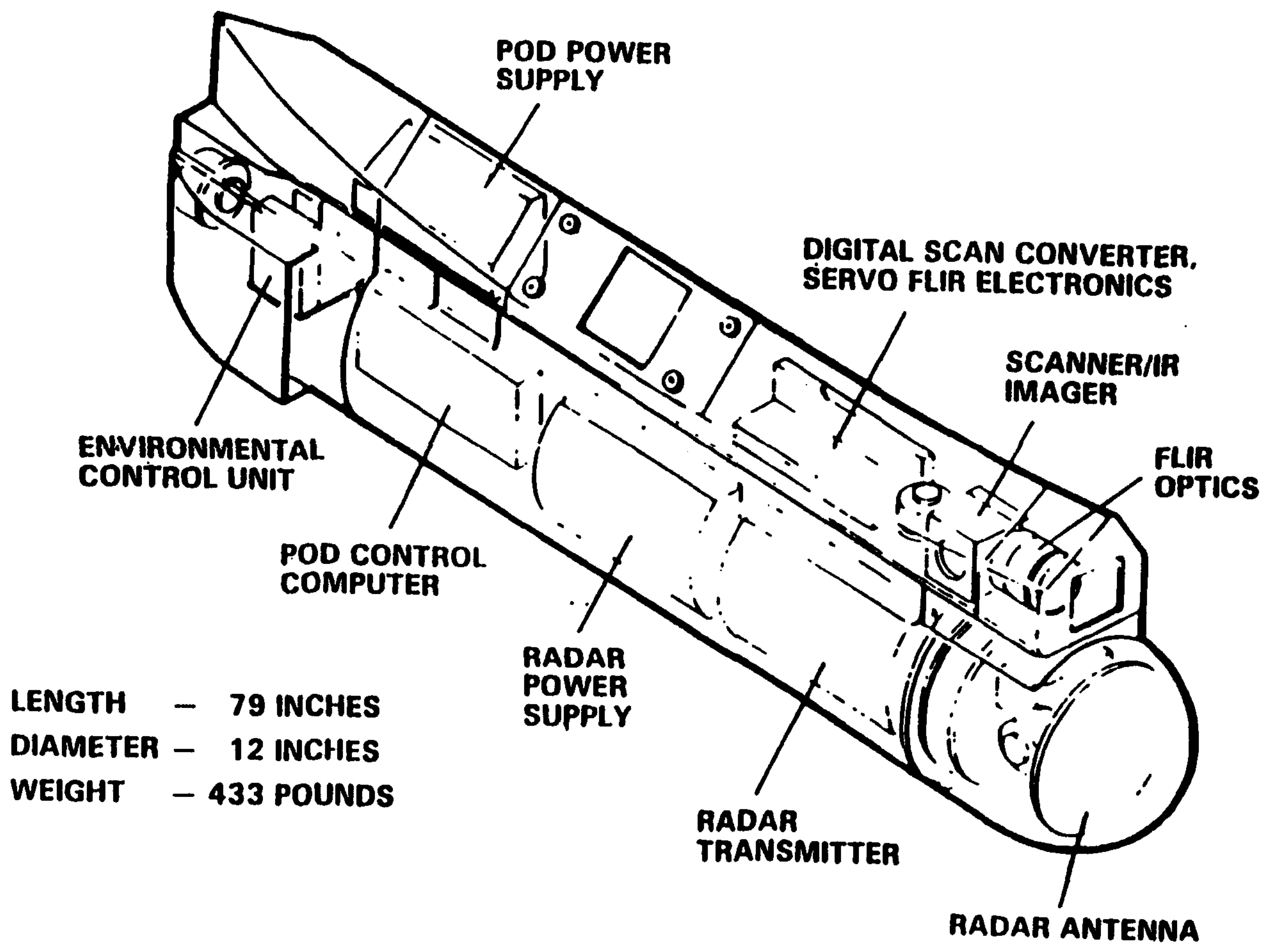
The LANTIRN Program consists of two prime hardware development efforts--the development of a heads-up-display (HUD) system for both the A-10 and the F-16 models, and the development of a Fire Control System (FCS) for use on the F-15, A-10, and F-16 aircraft. HUD production will be funded in the respective aircraft program lines. Marconi Avionics was awarded the HUD contract on 18 September 1990.

The Fire Control System consists of two separate sets of equipment each contained in its own pod suitable for underwing or under-fuselage attachment. Either or both pods can be carried, depending on the particular mission required. The equipment within the pods is supplied by a number of manufacturers, but overall responsibility rests with Martin Marietta Corporation as the prime contractor. The two pods are the AN/AAQ-13 navigation pod and the AN/AAQ-14 targeting pod.

<u>Navigation Pod</u>. The navigation pod, shown in figure 2, is pylon mounted and contains a wide field-of-view forward looking infrared radar (FLIR) sensor, terrain following radar (TFR), together with the associated power supply, pod control computer, and an environmental control unit (ECU). The navigation pod provides the pilot with night vision for safe flight at low level. The terrain following radar allows operation at very low altitudes with en route weather penetration and blind let-down capability.

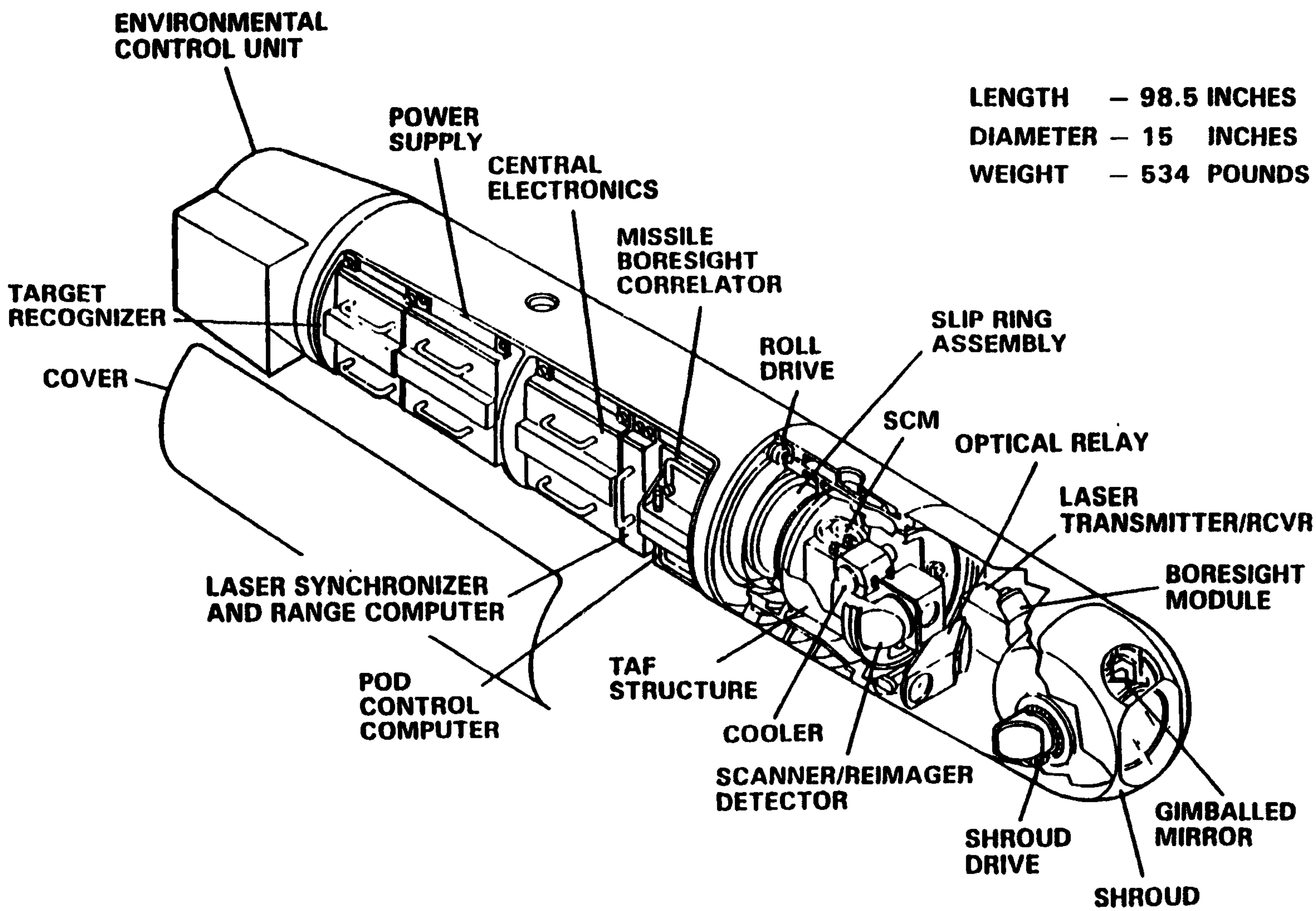
<u>Targeting Pod</u>. The targeting pod, shown in figure 3, is also pylon mounted and contains a wide and narrow field-of-view FLIR sensor, laser designator/ranger, automatic missile boresight correlator (MBC), automatic target recognizer (TR), pod control computer, power supply and environmental control unit (ECU). When the MBC and the TR are removed from the targeting pod, the remainder is referred to as the target designator subsystem. The TR is currently in advanced development and will be added as a preplanned product improvement to the targeting pod after competitive development and test.

<u>Target Designator Subsystem</u>. The target designator subsystem of the targeting pod is intended to provide first-pass attack capability at a greater stand-off range than conventional systems. The target designator subsystem provides the laser energy for illuminating and ranging targets for the delivery of conventional and laser-guided



[illegible]IRN Navigation Pod

Figure 2



LANTIRN Targeting Pod

Figure 3

ordnance. The unit is intended to be one of the most advanced systems of its kind. Of modular construction, this lightweight device will be controlled by a microprocessor and use digital interfaces to provide serial or parallel commands directly to the LANTIRN navigation pod. The target designator will have a self-contained, automatic or manually initiated built-in test capability, and will be fitted with connectors for automatic test equipment fault isolation checks.

ACQUISITION APPROACH

The LANTIRN development effort began in 1990, under a contract awarded to Martin Marietta by the USAF Aeronautical Systems Center (ASC), at Wright-Patterson AFB, Ohio.
The total system (Fire Control System) acquisition plan will consist of the following phases:

Engineering and Manufacturing Development - the EMD phase includes the design, development, fabrication, qualification, and test of six (6) FCS pod sets (6 target pods and 6 nav pods). The EMD was initiated in September of 1990.

Production - Production lot 1 is an option for thirty-four (34) pod sets. Five (5) follow-on production buys are planned to complete the buy of 720 pod sets. The buy schedule is as follows:

FY96	FY97	FY98	FY99	FY00	FY01	TOTAL
34	138	144	144	144	116	720

The targeting pod's target recognizer (TR) follows a separate schedule, with advanced development continuing through FY94, followed by an 18-month competitive (two-firms) EMD phase and TR system test. Production for TRs begins with Production Lot 2 and is the schedule is as follows:

FY97	FY98	FY99	FY00	FY01	TOTAL
124	192	144	144	116	720

TASKING

As a member of the C^3I Division, you have worked with Major Russell and Karen Lopez on several past CCAs. The same afternoon that Karen spoke with Major Russell, Karen briefed you on the LANTIRN CCA, informing you that you would be in charge of estimating the target designator subsystem (atch 1 WBS). You will be one of several analysts working on the LANTIRN CCA. The next morning Karen E-mailed you the following list of specific responsibilities:

1. Use the analogy method to estimate the EMD and Production recurring manufacturing costs for the target designator subsystem (subset of the Targeting Pod). Data concerning possible analogous systems and corresponding complexity factors developed by the LANTIRN program office engineering staff are provided in attachment 2.

2. Normalize the data for inflation (the base year will be 1990).

3. Develop a spreadsheet that automates your EMD and Production estimates. The spreadsheet should include the complexity factor and the learning curve computations.

4. Develop a spreadsheet that will integrate all subsystem estimates and produce an AF Form 1537 (Weapon System Summary) for both EMD and Production. Separate 1537s should be prepared for base year, then year, and current year dollars (6 1537s total). Cost data for the other subsystem estimates is found in the cost analyst input sheets, which were prepared by other members of the CCA team, in attachment 3.

5. Finally, provide written documentation of your process and the final spreadsheets. Please be brief and limit narrative sections to 3-4 pages.

Karen was kind enough to provide you with a copy of an analogous estimating flow chart she used for a past estimate (figure 4).

GROUND RULES and ASSUMPTIONS

1. Martin Marietta Corporation, the LANTIRN contractor, estimates that recurring costs for the target designator in EMD will be spread out over two years (60% in 92, 40% in 93).

2. The target designator is WBS element 1011 and includes only the design and prototype costs--nonrecurring dollars for such items as tooling, special test equipment, and facilities are not included (see attch 1).

3. The burden rates for G&A and profit are provided by Martin Marietta Corporation through the Forward Fixed Price Agreement proposals. The EMD rate is 1.21, while the Production rate is 1.27.

4. The estimates should be expressed in then year, current year, and base year dollars (FY90$).

5. For inflation/deflation use the January 1993 OSD Inflation Rates for 3600 (EMD) and 3010 (production) appropriations (attch 4).

ESTIMATING PROCESS CHART

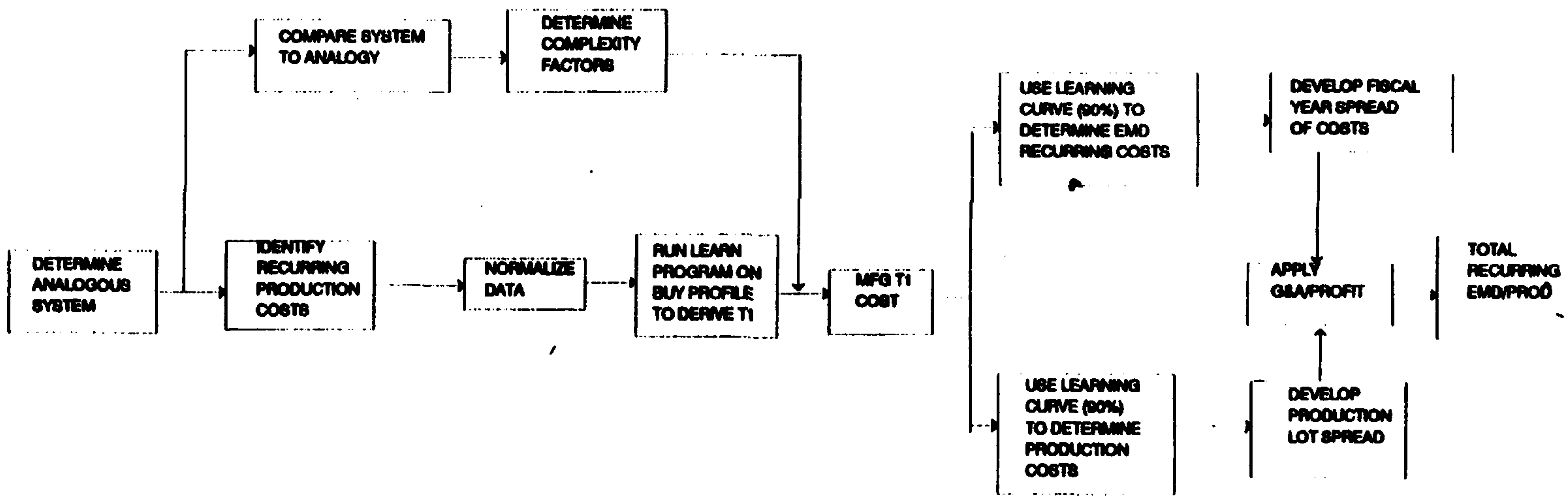


Figure 4

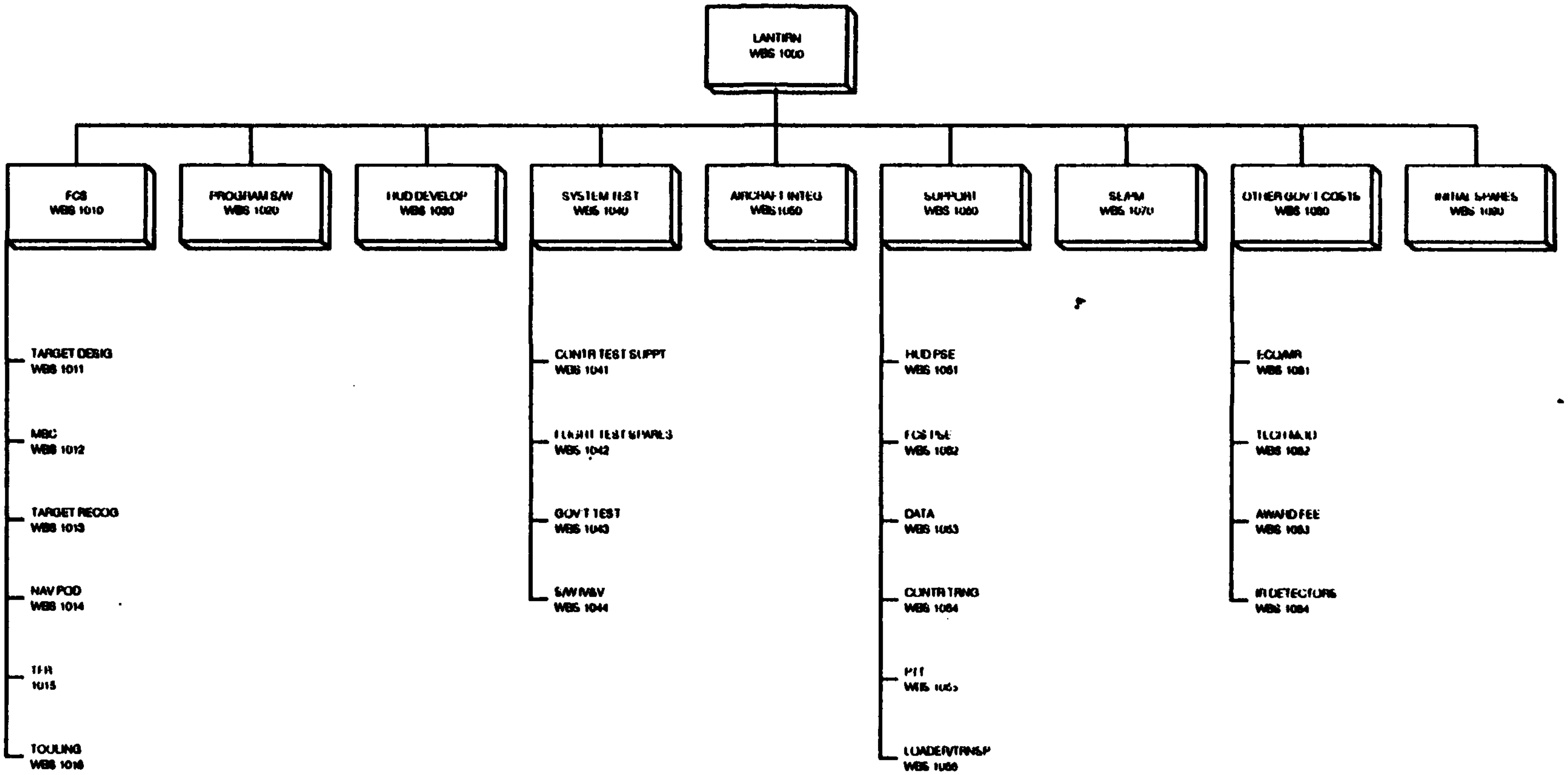
6. Martin Marietta Corporation uses a 90% cumulative average cost improvement curve to estimate both the EMD and production recurring pod costs. This learning rate is based on Martin Marietta's experience with similar past programs and projections for LANTIRN.

7. An Independent Technical Assessment Team (ITA) validated the complexity factor provided by the LANTIRN SPO. The learning curve slope provided by Martin Marietta was also validated by the ITA team.

8. The analogous system's fiscal year buy schedules with corresponding production costs are provided in attachment 5.

LANTIRN

PROGRAM WORK BREAKDOWN STRUCTURE



ATTACHMENT 2
ENGINEERING ASSESSMENT

ANALOGOUS SYSTEMS

PAVE TACK - This system was built by Ford Aerospace Corporation and is currently installed on the F-111E/F, RF-4E, and F-4E. Pave Tack provides target designation facilities for laser guided munition and range to target information for navigation and the delivery of conventional weapons. The Pave Tack system consists of a pod containing a turret-mounted FLIR detector and laser designator. The line of sight is controlled by the aircraft weapon system operator aided by a pod mounted digital computer. In a fully integrated configuration with other aircraft systems and weapons, the PAVE TACK system provides a day/night strike capability for high speed, precision weapon delivery from high or low altitudes.

Sharpshooter - The Sharpshooter system was built by Marconi Avionics as an upgrade system for the F-14 Tomcat. The Sharpshooter provides round-the-clock targeting capabilities, and has a narrow and wide FLIR sensor. The stabilized line of sight and continuous roll tracker can track either stationary or moving targets; it can also track a scene using area correlation. The laser designator and ranger have analog and digital aircraft interface and use programmable coding. When used in conjunction with Martin Marietta's Pathfinder (Navigation Pod), the Sharpshooter provides a day/night strike capability for high speed, precision weapon delivery from high or low altitudes.

The LANTIRN engineering staff analyzed the existing PAVE TACK and Sharpshooter electronics as compared to the target designator electronics in the LANTIRN system. To perform this comparison the LANTIRN system was broken out functionally into the following subsystems:

1. FLIR target acquisition and digital scan converter
2. Laser designator/ranger
3. Pod control computer
4. Gimbal/servo system
5. Power supply
6. Environmental control unit
7. Central electronics unit

PAVE TACK Analysis. Each of the above subsystems was examined against its analogous subsystem in PAVE TACK. Additionally, the engineering staff believes there are three weighting categories: 1) a cost weighting, representing how much each subsystem contributes to the total system cost 2) a design complexity weighting assigned by the engineers in the complexity worksheets shown below 3) a miniaturization factor for those items that must occupy less space in the LANTIRN program, but perform the same task as in the PAVE TACK. The three weightings are multiplied together to derive each subsystem's weighted development complexity factor. The sum of these factors should be applied to the Development T_1.

Table 1 shows how the complexity factor of 2.0 was derived for the FLIR Target Acquisition subsystem. Both the FLIR Module Assembly and the Digital Scan Converter Assembly were judged to be essentially the same as the comparative electronics in the PAVE TACK and therefore were assigned complexity values of 1.0. However, the LANTIRN FLIR Optics package has more lenses, mirrors, mounts and alignment requirements than in PAVE TACK--resulting in a complexity factor of 4.0. The complexity values for these three assemblies were given equal weighting and were averaged to come up with the total complexity factor of 2.0. Tables 1-5 illustrate the derivation of complexity factors for the laser designator/ranger, pod control computer, gimbal/servo system, and power supply.

For data availability reasons complexities for the environmental control unit (ECU) and central electronics units (CEU) were estimated somewhat differently. A complexity factor for the LANTIRN environmental control unit (ECU) of 3.0 was arrived at by considering the following items: 1) the LANTIRN ECU has to handle twice as much heat in a much smaller volume and 2) the LANTIRN ECU uses liquid coolanol, whereas the PAVE TACK ECU uses air cooling. Although there is no central electronics unit (CEU) in PAVE TACK, the LANTIRN CEU is very similar to the PAVE TACK pod control computer (PCC). Based on an absolute card count in both the PAVE TACK PCC and LANTIRN CEU, the CEU is 1.4 times as complex as the PCC. The existence of redundant card design in the CEU caused the engineers to reduce the complexity factor from 1.4 to 1.33. Thus since the LANTIRN PCC is 1.5 times as complex as the PAVE TACK pod control computer, as shown in table 3, then the LANTIRN CEU is 2.0 (1.5 x 1.33) times as complex as the PAVE TACK pod control computer.

Table 1
DERIVATION OF FLIR TARGET ACQUISITION COMPLEXITY

LANTIRN	PAVE TACK	COMPLEXITY	BASIS/COMMENTS
FLIR TARGET ACQUISITION SYSTEM			
1. FLIR OPTICS		4	MORE LENSES AND MIRRORS, MORE LENS/MIRROR MOUNTS, IMPROVED COATING AND MINIATURIZATION
A. LENSES (7)	(1)		
B. MIRRORS (4)	(1)		
C. I.R. WINDOW	(1)		
2. FLIR MODULE ASSEMBLY		1	
A. RE-IMAGER	X		
B. DETECTOR/COOLER	X		
C. SCANNER	X		
D. SLIDING LENS	X		
E. FOV (2 MOVABLE LENSES)	X		
3. DIGITAL SCAN CONVERTER	ACFT INT. UNIT	1	
A. SIGNAL CONVERTER MULTIPLEXER	CONVERSION UNIT		
B. REFORMATER	CRT DISPLAY		
C. SCAN SENSOR	X		
		TOTAL = 6/3 = 2	

Table 2
DERIVATION OF LASER DESIGNATOR/RANGER COMPLEXITY

LANTIRN	PAVE TACK	COMPLEXITY	BASIS/COMMENTS
LASER DESIGNATOR SYSTEM			
1. OPTICS PATH		1	NO CHANGE IN LASER TECHNOLOGY
A. LENSES (5)	(5)		
B. MIRRORS (1)	(7)		
C. PRISMS (5)	(0)		
2. TRANSMITTER/ RECEIVER	X	1	
3. LASER SYNCHRONISER /RANGE COMPUTER	X	1	
4. TRANSMITTER ELECTRONICS	X	1	
5. HV POWER SUPPLY	X	1	
		TOTAL = 5/5 = 1	

Table 3
DERIVATION OF POD CONTROL COMPUTER COMPLEXITY

LANTIRN	PAVE TACK	COMPLEXITY	BASIS/COMMENTS
POD CONTROL COMPUTER & BUS	DIGITAL PROCESSING UNIT (DPU)		
1. COMPUTER A. 6.15 KOPS B. 64 K MEMORY (17 BITS)	 312 KOPS 16.4K (16 BITS)	1.5	TWICE THE SPEED AND MEMORY OF PAVE TACK DPU. VARIOUS SUBSYSTEM INTERRUPTS AND SUBSYSTEM CONTROLS.
2. POD BUS (500K/SEC)	X	1.5	
		TOTAL = 3/2 = 1.5	

Table 4
DERIVATION OF GIMBAL/SERVO SYSTEM COMPLEXITY

LANTIRN	PAVE TACK	COMPLEXITY	BASIS/COMMENTS
GIMBAL/SERVO SYSTEM 1. PRIMARY MIRROR SERVOS	 SIGHTLINE STABILIZATION ASSEMBLY	 1	 ADDITIONAL COMPLEXITY DUE TO SLIP RING ASSEMBLY, FLIR DEROLL SERVO AND OPTICS SERVOS (FOV LENSES).
2. SLIP RING ASSEMBLY (4 PAIRS)		2	
3. NOSE SECTION SERVOS A. SHROUD SERVO (PITCH) B. FLIR DE-ROLL SERVO	 TURRET SERVO X	3 TOTAL = 6/3 = 2	

Table 5
DERIVATION OF POWER SUPPLY COMPLEXITY

LANTIRN	PAVE TACK	COMPLEXITY	BASIS/COMMENTS
POWER SUPPLY SYSTEM			
PROVIDES POWER TO: A. P.C.C B. M.B.C. C. TR D. COOLER E. SERVOS AND CEU F. TRACKER	 X X X X	2 TOTAL = 2	ADDITIONAL COMPLEXITY DUE TO MBC AND TR POWER REQUIREMENTS. 23 DC OUTPUTS AND WIDE INPUT RANGE. MULTIPLE CONTROL AND INTERFACE FUNCTIONS. LANTIRN/PAVE TACK = 400 AMPS/200 AMPS = 2

Provided below are the average unit costs for production and miniaturization factors for each of the PAVE TACK target designator subsystems.

Subsystem	Cost ($)	Miniaturization Factor
FLIR	4,840	1
Laser designator	1,320	1
Pod computer	1,760	1
Gimbal/servo	880	1.5
Power supply	1,210	1.5
ECU	990	1
CEU	No Analogy*	1

* While the CEU is similar in technical characteristics to the PCC, the CEU cost should only be half the PCC cost.

Note: the PAVE TACK and Sharpshooter prototype contained 15% structure and 85% electronics, as confirmed by the contractor's Cost Performance Report. The structural complexity of both systems was judged as being equal. The weighted complexity factor should be applied to the value of the electronic portion only to derive the Target Designator T_1 and the recurring cost of the 6 prototype units.

Sharpshooter Analysis. The complexity factors for the Sharpshooter system were derived in much the same manner as for the PAVE TACK. Tables 6-9 show how the various complexity factors were derived. For data availability reasons complexities for the environmental control unit (ECU), central electronics units (CEU), and Gimbal/servo system were estimated somewhat differently. A complexity factor for the LANTIRN environmental control unit (ECU) of 3.0 was arrived at by considering the following items: 1) the LANTIRN ECU has to handle twice as much heat in a much smaller volume and 2) the LANTIRN ECU uses liquid coolanol, whereas the Sharpshooter ECU uses air cooling.

There is no analogy for the CEU and Gimbal/servo System. As in the PAVE TACK system, the Sharpshooter PCC is quite similar to the LANTIRN CEU. Based on an absolute card count and accounting for redundant card design, it was determined that the LANTIRN CEU is 1.4 times as complex as the Sharpshooter PCC. Thus the CEU is 1.75 (1.25 X 1.4) times as complex as the Sharpshooter PCC.

Unique design considerations utilized in the Sharpshooter development effort resulted in a Gimbal/servo system that is not directly comparable to the LANTIRN system. A subjective assessment based on the basic differences in technology--due primarily to the lack of slip rings in the Sharpshooter--resulted in a complexity factor of 2.5 for the Gimbal/servo system.

Table 6
DERIVATION OF FLIR TARGET ACQUISITION COMPLEXITY

LANTIRN	SHARP-SHOOTER	COMPLEXITY	BASIS/COMMENTS
FLIR TARGET ACQUISITION SYSTEM			
1. FLIR OPTICS		2	MORE LENSES AND MIRRORS,
A. LENSES (7)	(4)		MORE LENS/MIRROR MOUNTS,
B. MIRRORS (4)	(2)		MINIATURIZATION
C. I.R. WINDOW	(1)		
2. FLIR MODULE ASSEMBLY		1	
A. RE-IMAGER	X		
B. DETECTOR/COOLER	X		
C. SCANNER	X		
D. SLIDING LENS	X		
E. FOV (2 MOVABLE LENSES)	X		
3. DIGITAL SCAN CONVERTER	ACFT INT. UNIT	1	
A. SIGNAL CONVERTER MULTIPLEXER	CONVERSION UNIT		
B. REFORMATER	CRT DISPLAY		
C. SCAN SENSOR	X		
		TOTAL = 4/3 = 1.3	

Table 7
DERIVATION OF LASER DESIGNATOR/RANGER COMPLEXITY

LANTIRN	SHARP-SHOOTER	COMPLEXITY	BASIS/COMMENTS
LASER DESIGNATOR SYSTEM			
1. OPTICS PATH		1	IMPROVED LASER
A. LENSES (5)	(4)		SYNCHRONIZATION THROUGH USE
B. MIRRORS (1)	(2)		OF OPTIC SCALARS. GREATER
C. PRISMS (5)	(1)		RANGE.
2. TRANSMITTER/ RECEIVER	X	1.5	
3. LASER SYNCHRONISER /RANGE COMPUTER	X	2	
4. TRANSMITTER ELECTRONICS	X	1	
5. HV POWER SUPPLY	X	1	
		TOTAL = 6.5/5=1.3	

Table 8

DERIVATION OF POD CONTROL COMPUTER COMPLEXITY

LANTIRN	SHARP-SHOOTER	COMPLEXITY	BASIS/COMMENTS
POD CONTROL COMPUTER & BUS	COMPUTER & BUS		GREATER SPEED AND MEMORY THAN SHARPSHOOTER.
1. COMPUTER		1.2	TWICE THE SPEED AND MEMORY OF PAVE TACK DPU. VARIOUS SUBSYSTEM INTERRUPTS AND SUBSYSTEM CONTROLS.
A. 615 KOPS	400 KOPS		
B. 64 K MEMORY (17 BITS)	64 K (17 BITS)		
2. POD BUS (500K/SEC)	350 K/SEC	1.3	
		TOTAL=2.5/2=1.2	

Table 9

DERIVATION OF POWER SUPPLY COMPLEXITY

LANTIRN	SHARP-SHOOTER	COMPLEXITY	BASIS/COMMENTS
POWER SUPPLY SYSTEM			
PROVIDES POWER TO:		1.5	ADDITIONAL COMPLEXITY DUE TO MBC REQUIREMENTS. 23 DC OUTPUTS AND WIDE INPUT RANGE. MULTIPLE CONTROL AND INTERFACE FUNCTIONS.
A. P.C.C	X		
B. M.B.C.			
C. TR			
D. COOLER	X		
E. SERVOS AND CEU	X		
F. TRACKER	X		
		TOTAL = 1.5	

The average unit costs for procurement and miniaturization factors for each of the Sharpshooter target designator subsystems are as follows:

Subsystem	Cost ($)	Miniaturization Factor
FLIR	5,649	1
Laser designator	1,965	1
Pod computer	2,205	1
Gimbal/servo	No analogy	1
Power supply	1,105	1.5
ECU	1,351	1
CEU	No analogy*	1.3

* While the CEU is similar in technical characteristics to the PCC, the CEU cost should only be half the PCC cost.

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Boyd **DATE:** 10 Jul 9X

WBS ELEMENT/NUMBER: Missile Boresight Correlator (MBC)/1012

DEVELOPMENT

BRIEF DESCRIPTION: Analogy estimate was used based on the Pershing II program. The TASC engineer's assessment of the complexity resulted in a 1.5 factor.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	6,668	5,705	2,321	0
	FY94	**FY95**	**FY96**	**FY97**
BY$	0	0	0	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	0	0	0	0
	TOTAL			
	14,694			

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Corrente **DATE:** 10 July 9X

WBS ELEMENT/NUMBER: Target Recognizer/1013

DEVELOPMENT

BRIEF DESCRIPTION: Special purpose processor which utilizes latest technology improvements. The TR must fit in a 10" x 10" x 6" area. The estimate was based on an analogous system--JTIDS-2 Data processor.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	19,909	8,467	4,008	4,450

	FY94	FY95	FY96	FY97
BY$	31,180	7,071	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
75,085

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Bond **DATE:** 10 July 9X

WBS ELEMENT/NUMBER: Navigation Pod/1014

DEVELOPMENT

BRIEF DESCRIPTION: Navigation pod used the same analogous systems from the target designator (PAVE TACK & Sharpshooter). The complexity factor was 1.63.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	7,900	13,525	7,261	0

	FY94	FY95	FY96	FY97
BY$	0	0	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
28,686

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Bailey **DATE**: 11 July 9X

WBS ELEMENT/NUMBER: Terrain Following Radar (TFR)/1015

DEVELOPMENT

BRIEF DESCRIPTION: The APQ-146 radar built by Texas Instrument was used for the analogy estimate. This radar was used on the F-111 & B-1B. The learning curve on similar radars has been 95% and therefore was used for LANTIRN.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	5,222	6,452	3,141	0

	FY94	FY95	FY96	FY97
BY$	0	0	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
14,815

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Simpson **DATE**: 9 July 9X

WBS ELEMENT/NUMBER: Software Development/1020

DEVELOPMENT

BRIEF DESCRIPTION: Three parametric cost estimating models were used--COCOMO, DOTY, & BOEING. Each model is built upon a different data base. The estimate by Martin Marietta was within the model's estimate & therefore deemed reasonable. The MMC proposal was used for the estimate.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	3,185	3,822	3,185

	FY94	FY95	FY96	FY97
BY$	2,549	0	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
12,741

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Ms Lopez **DATE:** 12 July 93

WBS ELEMENT/NUMBER: HUD Development/1030

DEVELOPMENT

BRIEF DESCRIPTION: Provided by ASC/FMC based on a firm-fixed price proposal from the HUD contractor (Marconi). Estimate includes: test support, data and SEPM.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	14,623	5,839	2,339	1,708
	FY94	**FY95**	**FY96**	**FY97**
BY$	1,571	1,734	243	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	0	0	0	0
	TOTAL			
	28,057			

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr Mundt **DATE**: 13 July 9X

WBS ELEMENT/NUMBER: Contractor Test Support/1041

DEVELOPMENT

BRIEF DESCRIPTION: 23% of the FCS non-recurring prime mission equipment. The factor was derived from an analogous system (PAVE TACK).

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	0	3,295	5,648
	FY94	**FY95**	**FY96**	**FY97**
BY$	5,647	5,647	4,235	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	0	0	0	0
	TOTAL			
	24,472			

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr Mundt **DATE:** 11 July 9X

WBS ELEMENT/NUMBER: Flight-Test Spares/1042

DEVELOPMENT

BRIEF DESCRIPTION: Flight test spares was 5% of the recurring prototype hardware value. The factor was provided by ESC/TOET, based on the team's description of the LANTIRN system & test program & TEMP.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	0	2,830	0

	FY94	FY95	FY96	FY97
BY$	0	767	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
3,597

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr Mundt **DATE:** 10 July 9X

WBS ELEMENT/NUMBER: Government Test/1043

DEVELOPMENT

BRIEF DESCRIPTION: Provided by ASD/ACC and are based upon the individual test centers' estimates of their requirements.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	972	4,614	5,518	7,062
	FY94	**FY95**	**FY96**	**FY97**
BY$	10,234	7,739	1,737	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	0	0	0	0

TOTAL
37,876

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Simpson **DATE:** 14 July 9X

WBS ELEMENT/NUMBER: Software IV&V/1044

DEVELOPMENT

BRIEF DESCRIPTION: 20 percent of system and support software development costs. The factor was derived from an analogous system. Discussions with software engineers at ESC indicated that 20% approximates the upper limit.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	636	2,140	981

	FY94	FY95	FY96	FY97
BY$	510	0	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
4,267

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr Rogers **DATE:** 11 July 93

WBS ELEMENT/NUMBER: Aircraft Integration/1050

DEVELOPMENT

BRIEF DESCRIPTION: The development of aircraft integration kits was estimated by the F-16 program office and reviewed by ASC/FMC. F-16 estimates represent sufficiency reviews of a budgetary estimate from General Dynamics.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	18,417	13,632	24,288	16,591
	FY94	**FY95**	**FY96**	**FY97**
BY$	10,452	4,334	2,797	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	0	0	0	0

TOTAL
90,511

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr Rogers **DATE:** 11 July 9X

WBS ELEMENT/NUMBER: HUD PSE/1061

DEVELOPMENT

BRIEF DESCRIPTION: Estimate provided by ASC/FMC based upon their sufficiency review of the program office estimate.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	229	2,640	5,116

	FY94	FY95	FY96	FY97
BY$	2,694	0	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
10,679

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr Rogers **DATE:** 8 July 9X

WBS ELEMENT/NUMBER: Fire Control System (FCS) Peculiar Support Equipment (PSE)/1062

DEVELOPMENT

BRIEF DESCRIPTION: Estimated by The Analytical Sciences Corporation (TASC) using a bottom's-up approach. The support Equipment Requirements Documents (SERDs) were individually priced and loaded for contractor and subcontractor loadings. Other support equipment requirements were based on an an analogous system.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	0	71,443	11,263

	FY94	FY95	FY96	FY97
BY$	23,274	442	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
106,422

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Boyd **DATE:** 13 July 9X

WBS ELEMENT/NUMBER: Data/1063

DEVELOPMENT

BRIEF DESCRIPTION: Estimated as 4% of the Fire Control System PME. The factor was derived using analogous programs.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	1,236	1,236	1,236	1,235

	FY94	FY95	FY96	FY97
BY$	1,235	1,235	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
7,413

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME· Captain Boyd **DATE:** 13 July 93

WBS ELEMENT/NUMBER: Contractor Training/1064

DEVELOPMENT

BRIEF DESCRIPTION: Based on analogous systems and subjectively estimated based on analyst and engineering assessment.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	238	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
238

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr Mundt **DATE:** 10 July 93

WBS ELEMENT/NUMBER: Part Task Trainer/1065

DEVELOPMENT

BRIEF DESCRIPTION: Estimate was furnished by ASC/YT (Trainer System Program Office). Estimate reviewed by the engineering and technical assessment teams.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	0	0	4,217
	FY94	**FY95**	**FY96**	**FY97**
BY$	7,462	2,463	0	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	0	0	0	0

TOTAL
14,142

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Simpson **DATE:** 14 July 9X

WBS ELEMENT/NUMBER: System Engineering/Program Management/1070

DEVELOPMENT

BRIEF DESCRIPTION: Twenty percent of FCS. Analysis of analogous system cost data resulted in a range from 19%-30%. Historically the higher the PME the smaller the ratio of SE/PM:PME. The LANTIRN program PME was relatively large therefore a smaller SE/PM factor was used.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	8,154	7,414	6,672	5,189

	FY94	FY95	FY96	FY97
BY$	5,187	3,447	0	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
36,063

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Ms Lopez **DATE**. 11 July 9X

WBS ELEMENT/NUMBER: ECO/MR/1081

DEVELOPMENT

BRIEF DESCRIPTION: Based on sufficiency review by ASC/FMC.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	0	0	23,713	9,711

	FY94	FY95	FY96	FY97
BY$	19,874	10,163	1,733	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
65,194

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Captain Bailey **DATE:** 10 July 9X

WBS ELEMENT/NUMBER: IR Detectors/1084

DEVELOPMENT

BRIEF DESCRIPTION: Estimates were throughput estimates from ASC/FMC.

($ in 000)

	FY90	FY91	FY92	FY93
BY$	3,416	3,057	2,841	2,371

	FY94	FY95	FY96	FY97
BY$	3,104	3,591	851	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

TOTAL
19,231

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Boyd **DATE:** 20 July 9X

WBS ELEMENT/NUMBER: Missile Boresight Correlator (MBC)/1012

PRODUCTION

BRIEF DESCRIPTION: The prototype T1 for MBC was run down the learning curve at 90% cum avg for the production lots. G&A/Profit was added on to the lot data

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	16,348	43,634

	FY98	FY99	FY00	FY01
BY$	39,603	36,883	35,154	27,390

	TOTAL
BY$	199,012

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Corrente **DATE:** 23 July 9X

WBS ELEMENT/NUMBER: Target Recognizer/1013

PRODUCTION

BRIEF DESCRIPTION: The prototype T1 for the TR had a penalty factor applied for the size of the unit. The engineers did not believe the penalty should be used in the production estimate. However, a production penalty was applied for the anticipated lower production yield. The new T1 was regressed down the learning curve to produce the lot costs. G&A/Profit was then applied.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	0	26,967

	FY98	FY99	FY00	FY01
BY$	32,647	22,351	21,295	16,588

	TOTAL
BY$	119,848

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Bond **DATE:** 22 Jul 9X

WBS ELEMENT/NUMBER: Navigation Pod/1014

PRODUCTION

BRIEF DESCRIPTION: The prototype T1 was run down the learning curve for the Nav pod. The G&A/Profit was then applied accordingly.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	51,138	136,481

	FY98	FY99	FY00	FY01
BY$	123,875	115,372	109,960	85,679

	TOTAL
BY $	622,505

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Bailey **DATE:** 22 Jul 9X

WBS ELEMENT/NUMBER: Terrain Following Radar TFR/1015

PRODUCTION

BRIEF DESCRIPTION: The prototype T1 value was run down the 95 percent unit slope (T1's experience curve) to produce the TF radar recurring production

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	25,992	81,948

	FY98	FY99	FY00	FY01
BY$	79,953	77,240	75,460	59,809

	TOTAL
BY$	400,402

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Bond **DATE:** 22 Jul 9X

WBS ELEMENT/NUMBER: Tooling/1016

PRODUCTION

BRIEF DESCRIPTION: Tooling costs was calculated by appplying a factor of 13.45 to the LANTIRN FCS Production T1. It was from the PAVE TACK system. The PAVE TACK system was used because insight was available on the specific non-recurring data. The tooling category includes the cost for basic and rate tooling, special test equipment, manufacturing layout, and facilities.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0
	FY94	**FY95**	**FY96**	**FY97**
BY$	0	0	94,202	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	6,086	0	0	0

	TOTAL
BY$	100,288

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr. Rogers **DATE:** 21 Jul 9X

WBS ELEMENT/NUMBER: FCS Peculiar Support Equipemnt/1061

PRODUCTION

BRIEF DESCRIPTION: Requirements for 43 sets of FCS support equipment at three levels of maintenance were costed using a bottoms-up approach. ASC/FMC added an amount to procure pod loaders and transponders based upon their sufficiency review of the estimated dollar requirements.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	0	155,824

	FY98	FY99	FY00	FY01
BY$	62,590	62,590	62,590	54,764

	TOTAL
BY$	398,358

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Boyd **DATE:** 23 Jul 9X

WBS ELEMENT/NUMBER: Data/1063

PRODUCTION

BRIEF DESCRIPTION: Production data was estimated at 1 percent of the FCS Prime Mission Equipment. That factor has been used on ESC programs with large quantity buys (e.g., TACAN, JTIDS, SEEK TALK) and is consistent with recent usage at ASC.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	2,551	4,750

	FY98	FY99	FY00	FY01
BY$	4,393	4,038	3,867	3,024

	TOTAL
BY$	22,623

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Boyd **DATE:** 19 Jul 9X

WBS ELEMENT/NUMBER: Loaders/transporters/1066

PRODUCTION

BRIEF DESCRIPTION: Estimates were extracted from firm contractor proposals

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	2,608	1,739

	FY98	FY99	FY00	FY01
BY$	1,594	1,594	1,304	0

	TOTAL
BY$	8,839

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Simpson **DATE:** 22 Jul 9X

WBS ELEMENT/NUMBER: Systems Engineering/Program Mangement /1070

PRODUCTION

BRIEF DESCRIPTION: The estimating/technical teams evaluated the peak staff loading in the PAVE TACK, TADS/PNVS, and Sharpshooter production programs. The evaluation disclosed that peak loading on the former was about 85 personnel and, on the later about 95 personnel. The team concluded that peak loading on LANTIRN should be approximately 90 personnel in FY96 and estimated their costs based upon MMC average 1992 SE/PM labor rates used in the May 1992 proposal.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	20,692	7,445

	FY98	FY99	FY00	FY01
BY$	6,551	6,427	6,372	6,340

	TOTAL
BY$	53,827

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Corrente **DATE:** 22 Jul 9X

WBS ELEMENT/NUMBER: Tech Modernization/1082

PRODUCTION

BRIEF DESCRIPTION: Technology Modernization, as based on negotiated contract and priced options.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	4,772	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

	TOTAL
BY$	4,772

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Ms. Lopez **DATE:** 30 Jul 9X

WBS ELEMENT/NUMBER: Engineering Change Order/Reserve Mgt/1081

PRODUCTION

BRIEF DESCRIPTION: ECO/MR was based on a sufficiency review of the ASC/FMC estimate.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	44,919	57,960

	FY98	FY99	FY00	FY01
BY$	23,184	23,184	23,184	10,143

	TOTAL
BY$	182,574

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Corrente **DATE:** 25 Jul 9X

WBS ELEMENT/NUMBER: Award Fee/1083

PRODUCTION

BRIEF DESCRIPTION: Award Fee was based on prior contractual award fee arrangement.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0
	FY94	**FY95**	**FY96**	**FY97**
BY$	0	0	12,461	0
	FY98	**FY99**	**FY00**	**FY01**
BY$	0	0	0	0

	TOTAL
BY$	12,461

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Mr. Mundt **DATE:** 24 Jul 9X

WBS ELEMENT/NUMBER: IR Detectors/1084

PRODUCTION

BRIEF DESCRIPTION: The IR Detectors were extracted from firm contractor proposals.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0

	FY94	FY95	FY96	FY97
BY$	0	0	3,111	0

	FY98	FY99	FY00	FY01
BY$	0	0	0	0

	TOTAL
BY$	3,111

COST ANALYST INPUT SHEET

LANTIRN PROGRAM

ANALYST NAME: Capt Simpson **DATE:** 22 Jul 9X

WBS ELEMENT/NUMBER: Initial Spares/1090

PRODUCTION

BRIEF DESCRIPTION: Initial Spares are estimated by applying AFLC cost factor to the program estimates for FCS.

($ in 000)

	FY90	FY91	FY92	FY93
BY $	0	0	0	0
	FY94	**FY95**	**FY96**	**FY97**
BY$	0	0	52,599	177,792
	FY98	**FY99**	**FY00**	**FY01**
BY$	41,586	0	0	0
	TOTAL			
BY$	271,977			

** RAW **   DEVELOPMENT (3600)   OSD RATES   MARCH 1993

FISCAL YEAR	1981	1982	BASE YEAR 1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.000	0.916	0.873	0.841	0.813	0.791	0.770	0.748	0.718	0.690	0.662	0.644	0.629
1982	1.092	1.000	0.953	0.918	0.888	0.864	0.841	0.817	0.784	0.754	0.723	0.703	0.686
1983	1.146	1.049	1.000	0.963	0.932	0.906	0.883	0.857	0.822	0.791	0.758	0.737	0.720
1984	1.189	1.089	1.038	1.000	0.967	0.941	0.916	0.889	0.854	0.821	0.787	0.765	0.747
1985	1.229	1.126	1.073	1.034	1.000	0.973	0.947	0.920	0.883	0.849	0.814	0.791	0.773
1986	1.264	1.157	1.103	1.063	1.028	1.000	0.974	0.945	0.907	0.872	0.836	0.814	0.795
1987	1.298	1.189	1.133	1.092	1.056	1.027	1.000	0.971	0.932	0.896	0.859	0.836	0.816
1988	1.337	1.224	1.167	1.124	1.087	1.058	1.030	1.000	0.960	0.923	0.885	0.861	0.840
1989	1.393	1.276	1.216	1.172	1.133	1.102	1.073	1.042	1.000	0.962	0.922	0.897	0.876
1990	1.449	1.327	1.265	1.218	1.178	1.146	1.116	1.084	1.040	1.000	0.959	0.933	0.911
1991	1.511	1.384	1.319	1.271	1.229	1.196	1.164	1.130	1.085	1.043	1.000	0.973	0.950
1992	1.553	1.423	1.356	1.306	1.264	1.229	1.197	1.162	1.115	1.072	1.028	1.000	0.977
1993	1.591	1.457	1.389	1.338	1.294	1.259	1.226	1.190	1.142	1.098	1.053	1.024	1.000
1994	1.629	1.492	1.422	1.370	1.325	1.289	1.255	1.218	1.169	1.124	1.078	1.049	1.024
1995	1.666	1.526	1.455	1.401	1.355	1.318	1.284	1.246	1.196	1.150	1.103	1.073	1.048
1996	1.705	1.561	1.488	1.434	1.387	1.349	1.313	1.275	1.224	1.177	1.128	1.097	1.072
1997	1.742	1.595	1.521	1.465	1.417	1.378	1.342	1.303	1.251	1.202	1.153	1.122	1.095
1998	1.781	1.631	1.554	1.497	1.448	1.409	1.372	1.332	1.278	1.229	1.178	1.146	1.119
1999	1.820	1.666	1.589	1.530	1.480	1.440	1.402	1.361	1.306	1.256	1.204	1.171	1.144
2000	1.860	1.703	1.623	1.564	1.513	1.471	1.433	1.391	1.335	1.284	1.231	1.197	1.169
2001	1.901	1.741	1.659	1.598	1.546	1.504	1.464	1.422	1.364	1.312	1.258	1.224	1.195
2002	1.942	1.779	1.696	1.634	1.580	1.537	1.496	1.453	1.394	1.341	1.285	1.250	1.221
2003	1.985	1.818	1.733	1.670	1.615	1.571	1.529	1.485	1.425	1.370	1.314	1.278	1.248
2004	2.029	1.858	1.771	1.706	1.650	1.605	1.563	1.518	1.456	1.400	1.343	1.306	1.275
2005	2.074	1.899	1.810	1.744	1.687	1.641	1.597	1.551	1.488	1.431	1.372	1.335	1.303
2006	2.119	1.941	1.850	1.782	1.724	1.677	1.633	1.585	1.521	1.463	1.402	1.364	1.332
2007	2.166	1.983	1.891	1.821	1.762	1.714	1.669	1.620	1.555	1.495	1.433	1.394	1.361
2008	2.213	2.027	1.932	1.861	1.800	1.751	1.705	1.656	1.589	1.528	1.465	1.425	1.391
2009	2.262	2.072	1.975	1.902	1.840	1.790	1.743	1.692	1.624	1.561	1.497	1.456	1.422
2010	2.312	2.117	2.018	1.944	1.880	1.829	1.781	1.729	1.659	1.596	1.530	1.488	1.453
2011	2.363	2.164	2.063	1.987	1.922	1.869	1.820	1.767	1.696	1.631	1.564	1.521	1.485
2012	2.415	2.211	2.108	2.031	1.964	1.911	1.860	1.806	1.733	1.667	1.598	1.554	1.518
2013	2.468	2.260	2.154	2.075	2.007	1.953	1.901	1.846	1.771	1.703	1.633	1.589	1.551
2014	2.522	2.310	2.202	2.121	2.051	1.996	1.943	1.886	1.810	1.741	1.669	1.624	1.586
2015	2.578	2.360	2.250	2.168	2.097	2.039	1.986	1.928	1.850	1.779	1.706	1.659	1.620
2016	2.634	2.412	2.300	2.215	2.143	2.084	2.029	1.970	1.891	1.818	1.743	1.696	1.656
2017	2.692	2.465	2.350	2.264	2.190	2.130	2.074	2.014	1.933	1.858	1.782	1.733	1.692
2018	2.751	2.520	2.402	2.314	2.238	2.177	2.120	2.058	1.975	1.899	1.821	1.771	1.730
2019	2.812	2.575	2.455	2.365	2.287	2.225	2.166	2.103	2.019	1.941	1.861	1.810	1.768
2020	2.874	2.632	2.509	2.417	2.338	2.274	2.214	2.150	2.063	1.984	1.902	1.850	1.807
2021	2.937	2.690	2.564	2.470	2.389	2.324	2.263	2.197	2.108	2.027	1.944	1.891	1.846
2022	3.002	2.749	2.620	2.524	2.441	2.375	2.313	2.245	2.155	2.072	1.986	1.932	1.887
2023	3.068	2.809	2.678	2.580	2.495	2.427	2.363	2.295	2.202	2.117	2.030	1.975	1.929
2024	3.135	2.871	2.737	2.637	2.550	2.481	2.415	2.345	2.251	2.164	2.075	2.018	1.971
2025	3.204	2.934	2.797	2.695	2.606	2.535	2.469	2.397	2.300	2.212	2.120	2.063	2.014
2026	3.275	2.999	2.859	2.754	2.664	2.591	2.523	2.449	2.351	2.260	2.167	2.108	2.059

** WEIGHTED **   DEVELOPMENT (3600)   OSD RATES   MARCH 1993

FISCAL YEAR	BASE YEAR 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.044	0.956	0.911	0.878	0.849	0.826	0.804	0.781	0.749	0.721	0.691	0.672	0.656
1982	1.116	1.022	0.974	0.939	0.908	0.883	0.860	0.835	0.801	0.770	0.739	0.718	0.702
1983	1.168	1.069	1.019	0.982	0.950	0.924	0.900	0.873	0.838	0.806	0.773	0.752	0.734
1984	1.213	1.111	1.059	1.020	0.987	0.960	0.935	0.907	0.871	0.837	0.803	0.781	0.763
1985	1.254	1.148	1.095	1.055	1.020	0.992	0.966	0.938	0.900	0.866	0.830	0.807	0.788
1986	1.284	1.176	1.121	1.080	1.045	1.016	0.990	0.961	0.922	0.887	0.850	0.827	0.807
1987	1.343	1.230	1.172	1.129	1.092	1.062	1.035	1.004	0.964	0.927	0.889	0.864	0.844
1988	1.386	1.269	1.210	1.166	1.127	1.097	1.068	1.037	0.995	0.957	0.917	0.892	0.871
1989	1.432	1.311	1.250	1.204	1.165	1.133	1.103	1.071	1.028	0.988	0.947	0.922	0.900
1990	1.489	1.363	1.300	1.252	1.211	1.178	1.147	1.114	1.069	1.028	0.985	0.958	0.936
1991	1.543	1.413	1.347	1.298	1.255	1.221	1.189	1.154	1.108	1.065	1.021	0.993	0.970
1992	1.581	1.448	1.380	1.329	1.286	1.251	1.218	1.182	1.135	1.091	1.046	1.018	0.994
1993	1.618	1.482	1.413	1.361	1.316	1.281	1.247	1.211	1.162	1.117	1.071	1.042	1.017
1994	1.656	1.517	1.446	1.393	1.347	1.311	1.276	1.239	1.189	1.143	1.096	1.066	1.041
1995	1.694	1.551	1.479	1.425	1.378	1.340	1.305	1.267	1.216	1.169	1.121	1.091	1.065
1996	1.732	1.586	1.512	1.457	1.409	1.371	1.335	1.296	1.244	1.196	1.146	1.115	1.089
1997	1.770	1.621	1.546	1.489	1.440	1.401	1.364	1.324	1.271	1.222	1.172	1.140	1.113
1998	1.809	1.657	1.580	1.522	1.472	1.432	1.394	1.353	1.299	1.249	1.197	1.165	1.137
1999	1.849	1.693	1.614	1.555	1.504	1.463	1.425	1.383	1.327	1.276	1.224	1.190	1.162
2000	1.890	1.731	1.650	1.589	1.537	1.495	1.456	1.414	1.357	1.304	1.251	1.217	1.188
2001	1.931	1.769	1.686	1.624	1.571	1.528	1.488	1.445	1.386	1.333	1.278	1.243	1.214
2002	1.974	1.808	1.723	1.660	1.606	1.562	1.521	1.476	1.417	1.362	1.306	1.271	1.241
2003	2.017	1.847	1.761	1.697	1.641	1.596	1.554	1.509	1.448	1.392	1.335	1.299	1.268
2004	2.062	1.888	1.800	1.734	1.677	1.631	1.588	1.542	1.480	1.423	1.364	1.327	1.296
2005	2.107	1.930	1.839	1.772	1.714	1.667	1.623	1.576	1.513	1.454	1.394	1.356	1.325
2006	2.153	1.972	1.880	1.811	1.752	1.704	1.659	1.611	1.546	1.486	1.425	1.386	1.354
2007	2.201	2.015	1.921	1.851	1.790	1.741	1.696	1.646	1.580	1.519	1.456	1.417	1.384
2008	2.249	2.060	1.964	1.892	1.829	1.780	1.733	1.682	1.615	1.552	1.488	1.448	1.414
2009	2.299	2.105	2.007	1.933	1.870	1.819	1.771	1.719	1.650	1.587	1.521	1.480	1.445
2010	2.349	2.151	2.051	1.976	1.911	1.859	1.810	1.757	1.686	1.622	1.555	1.512	1.477
2011	2.401	2.199	2.096	2.019	1.953	1.900	1.850	1.796	1.724	1.657	1.589	1.546	1.509
2012	2.454	2.247	2.142	2.064	1.996	1.942	1.890	1.835	1.761	1.694	1.624	1.580	1.543
2013	2.508	2.297	2.189	2.109	2.040	1.984	1.932	1.876	1.800	1.731	1.660	1.614	1.577
2014	2.563	2.347	2.237	2.156	2.085	2.028	1.975	1.917	1.840	1.769	1.696	1.650	1.611
2015	2.619	2.399	2.287	2.203	2.131	2.072	2.018	1.959	1.880	1.808	1.733	1.686	1.647
2016	2.677	2.451	2.337	2.251	2.177	2.118	2.062	2.002	1.922	1.848	1.772	1.723	1.683
2017	2.736	2.505	2.388	2.301	2.225	2.165	2.108	2.046	1.964	1.888	1.811	1.761	1.720
2018	2.796	2.561	2.441	2.352	2.274	2.212	2.154	2.091	2.007	1.930	1.850	1.800	1.758
2019	2.858	2.617	2.495	2.403	2.324	2.261	2.202	2.137	2.051	1.972	1.891	1.840	1.796
2020	2.920	2.674	2.550	2.456	2.375	2.311	2.250	2.184	2.096	2.016	1.933	1.880	1.836

** RAW **   AIRCRAFT PROCUREMENT (3010)   OSD RATES   MARCH 1993

FISCAL YEAR	BASE YEAR 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.000	0.912	0.837	0.775	0.750	0.729	0.710	0.689	0.662	0.636	0.610	0.593	0.579
1982	1.096	1.000	0.917	0.849	0.822	0.799	0.778	0.755	0.725	0.697	0.668	0.650	0.635
1983	1.195	1.090	1.000	0.926	0.895	0.871	0.848	0.823	0.790	0.760	0.729	0.709	0.692
1984	1.290	1.177	1.080	1.000	0.967	0.941	0.916	0.889	0.854	0.821	0.787	0.765	0.747
1985	1.334	1.217	1.117	1.034	1.000	0.973	0.947	0.920	0.883	0.849	0.814	0.791	0.773
1986	1.371	1.251	1.148	1.063	1.028	1.000	0.974	0.945	0.907	0.872	0.836	0.814	0.795
1987	1.408	1.285	1.179	1.092	1.056	1.027	1.000	0.971	0.932	0.896	0.859	0.836	0.816
1988	1.451	1.324	1.214	1.124	1.087	1.058	1.030	1.000	0.960	0.923	0.885	0.861	0.840
1989	1.512	1.379	1.265	1.172	1.133	1.102	1.073	1.042	1.000	0.962	0.922	0.897	0.876
1990	1.572	1.434	1.316	1.218	1.178	1.146	1.116	1.084	1.040	1.000	0.959	0.933	0.911
1991	1.640	1.496	1.373	1.271	1.229	1.196	1.164	1.130	1.085	1.043	1.000	0.973	0.950
1992	1.686	1.538	1.411	1.306	1.264	1.229	1.197	1.162	1.115	1.072	1.028	1.000	0.977
1993	1.726	1.575	1.445	1.338	1.294	1.259	1.226	1.190	1.142	1.098	1.053	1.024	1.000
1994	1.768	1.613	1.480	1.370	1.325	1.289	1.255	1.218	1.169	1.124	1.078	1.049	1.024
1995	1.808	1.650	1.514	1.401	1.355	1.318	1.284	1.246	1.196	1.150	1.103	1.073	1.048
1996	1.850	1.688	1.548	1.434	1.387	1.349	1.313	1.275	1.224	1.177	1.128	1.097	1.072
1997	1.890	1.725	1.582	1.465	1.417	1.378	1.342	1.303	1.251	1.202	1.153	1.122	1.095
1998	1.932	1.763	1.617	1.497	1.448	1.409	1.372	1.332	1.278	1.229	1.178	1.146	1.119
1999	1.975	1.802	1.653	1.530	1.480	1.440	1.402	1.361	1.306	1.256	1.204	1.171	1.144
2000	2.018	1.841	1.689	1.564	1.513	1.471	1.433	1.391	1.335	1.284	1.231	1.197	1.169
2001	2.062	1.882	1.726	1.598	1.546	1.504	1.464	1.422	1.364	1.312	1.258	1.224	1.195
2002	2.108	1.923	1.764	1.634	1.580	1.537	1.496	1.453	1.394	1.341	1.285	1.250	1.221
2003	2.154	1.965	1.803	1.670	1.615	1.571	1.529	1.485	1.425	1.370	1.314	1.278	1.248
2004	2.202	2.009	1.843	1.706	1.650	1.605	1.563	1.518	1.456	1.400	1.343	1.306	1.275
2005	2.250	2.053	1.883	1.744	1.687	1.641	1.597	1.551	1.488	1.431	1.372	1.335	1.303
2006	2.299	2.098	1.925	1.782	1.724	1.677	1.633	1.585	1.521	1.463	1.402	1.364	1.332
2007	2.350	2.144	1.967	1.821	1.762	1.714	1.669	1.620	1.555	1.495	1.433	1.394	1.361
2008	2.402	2.191	2.010	1.861	1.800	1.751	1.705	1.656	1.589	1.528	1.465	1.425	1.391
2009	2.455	2.240	2.055	1.902	1.840	1.790	1.743	1.692	1.624	1.561	1.497	1.456	1.422
2010	2.509	2.289	2.100	1.944	1.880	1.829	1.781	1.729	1.659	1.596	1.530	1.488	1.453
2011	2.564	2.339	2.146	1.987	1.922	1.869	1.820	1.767	1.696	1.631	1.564	1.521	1.485
2012	2.620	2.391	2.193	2.031	1.964	1.911	1.860	1.806	1.733	1.667	1.598	1.554	1.518
2013	2.678	2.443	2.242	2.075	2.007	1.953	1.901	1.846	1.771	1.703	1.633	1.589	1.551
2014	2.737	2.497	2.291	2.121	2.051	1.996	1.943	1.886	1.810	1.741	1.669	1.624	1.586
2015	2.797	2.552	2.341	2.168	2.097	2.039	1.986	1.928	1.850	1.779	1.706	1.659	1.620
2016	2.858	2.608	2.393	2.215	2.143	2.084	2.029	1.970	1.891	1.818	1.743	1.696	1.656
2017	2.921	2.665	2.445	2.264	2.190	2.130	2.074	2.014	1.933	1.858	1.782	1.733	1.692
2018	2.986	2.724	2.499	2.314	2.238	2.177	2.120	2.058	1.975	1.899	1.821	1.771	1.730
2019	3.051	2.784	2.554	2.365	2.287	2.225	2.166	2.103	2.019	1.941	1.861	1.810	1.768
2020	3.118	2.845	2.610	2.417	2.338	2.274	2.214	2.150	2.063	1.984	1.902	1.850	1.807
2021	3.187	2.908	2.668	2.470	2.389	2.324	2.263	2.197	2.108	2.027	1.944	1.891	1.846
2022	3.257	2.972	2.726	2.524	2.441	2.375	2.313	2.245	2.155	2.072	1.986	1.932	1.887
2023	3.329	3.037	2.786	2.580	2.495	2.427	2.363	2.295	2.202	2.117	2.030	1.975	1.929
2024	3.402	3.104	2.848	2.637	2.550	2.481	2.415	2.345	2.251	2.164	2.075	2.018	1.971
2025	3.477	3.172	2.910	2.695	2.606	2.535	2.469	2.397	2.300	2.212	2.120	2.063	2.014
2026	3.553	3.242	2.974	2.754	2.664	2.591	2.523	2.449	2.351	2.260	2.167	2.108	2.059

** WEIGHTED ** AIRCRAFT PROCUREMENT (3010) OSD RATES MARCH 1993

FISCAL YEAR	BASE YEAR 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.167	1.065	0.977	0.905	0.875	0.851	0.829	0.805	0.772	0.742	0.712	0.692	0.676
1982	1.228	1.121	1.028	0.952	0.921	0.896	0.872	0.847	0.813	0.781	0.749	0.729	0.712
1983	1.302	1.188	1.090	1.009	0.976	0.949	0.924	0.898	0.861	0.828	0.794	0.772	0.754
1984	1.358	1.239	1.136	1.052	1.018	0.990	0.964	0.936	0.898	0.864	0.828	0.805	0.786
1985	1.401	1.279	1.173	1.086	1.050	1.022	0.995	0.966	0.927	0.891	0.855	0.831	0.812
1986	1.452	1.325	1.215	1.125	1.088	1.059	1.031	1.001	0.961	0.924	0.886	0.861	0.841
1987	1.511	1.379	1.265	1.171	1.133	1.102	1.073	1.042	1.000	0.961	0.922	0.897	0.876
1988	1.586	1.447	1.328	1.229	1.189	1.157	1.126	1.093	1.049	1.009	0.967	0.941	0.919
1989	1.640	1.496	1.373	1.271	1.229	1.196	1.164	1.130	1.085	1.043	1.000	0.973	0.950
1990	1.689	1.541	1.413	1.309	1.266	1.231	1.199	1.164	1.117	1.074	1.030	1.002	0.978
1991	1.760	1.606	1.473	1.364	1.319	1.283	1.250	1.213	1.164	1.120	1.073	1.044	1.020
1992	1.778	1.622	1.488	1.378	1.332	1.296	1.262	1.225	1.176	1.131	1.084	1.055	1.030
1993	1.819	1.659	1.522	1.410	1.363	1.326	1.291	1.254	1.203	1.157	1.109	1.079	1.054
1994	1.860	1.697	1.557	1.442	1.394	1.356	1.321	1.282	1.230	1.183	1.134	1.103	1.078
1995	1.901	1.735	1.592	1.474	1.425	1.386	1.350	1.311	1.258	1.209	1.160	1.128	1.102
1996	1.943	1.773	1.627	1.506	1.457	1.417	1.380	1.340	1.286	1.236	1.185	1.153	1.126
1997	1.986	1.812	1.662	1.539	1.489	1.448	1.410	1.369	1.314	1.263	1.211	1.178	1.151
1998	2.030	1.852	1.699	1.573	1.521	1.480	1.441	1.399	1.343	1.291	1.238	1.204	1.176
1999	2.074	1.893	1.736	1.608	1.555	1.513	1.473	1.430	1.372	1.319	1.265	1.231	1.202
2000	2.120	1.934	1.775	1.643	1.589	1.546	1.505	1.461	1.402	1.348	1.293	1.258	1.228
2001	2.167	1.977	1.814	1.679	1.624	1.580	1.538	1.493	1.433	1.378	1.321	1.285	1.255
2002	2.214	2.020	1.854	1.716	1.660	1.615	1.572	1.526	1.465	1.408	1.350	1.314	1.283
2003	2.263	2.065	1.894	1.754	1.696	1.650	1.607	1.560	1.497	1.439	1.380	1.343	1.311
2004	2.313	2.110	1.936	1.793	1.734	1.686	1.642	1.594	1.530	1.471	1.410	1.372	1.340
2005	2.364	2.157	1.979	1.832	1.772	1.724	1.678	1.629	1.564	1.503	1.442	1.402	1.369
2006	2.416	2.204	2.022	1.872	1.811	1.761	1.715	1.665	1.598	1.537	1.473	1.433	1.400
2007	2.469	2.253	2.067	1.913	1.851	1.800	1.753	1.702	1.633	1.570	1.506	1.465	1.430
2008	2.523	2.302	2.112	1.956	1.891	1.840	1.791	1.739	1.669	1.605	1.539	1.497	1.462
2009	2.579	2.353	2.159	1.999	1.933	1.880	1.831	1.777	1.706	1.640	1.573	1.530	1.494
2010	2.635	2.405	2.206	2.043	1.975	1.922	1.871	1.817	1.743	1.676	1.607	1.563	1.527
2011	2.693	2.457	2.255	2.088	2.019	1.964	1.912	1.857	1.782	1.713	1.643	1.598	1.560
2012	2.753	2.511	2.304	2.133	2.063	2.007	1.954	1.897	1.821	1.751	1.679	1.633	1.595
2013	2.813	2.567	2.355	2.180	2.109	2.051	1.997	1.939	1.861	1.789	1.716	1.669	1.630
2014	2.875	2.623	2.407	2.228	2.155	2.096	2.041	1.982	1.902	1.829	1.753	1.706	1.666
2015	2.938	2.681	2.460	2.277	2.202	2.143	2.086	2.025	1.944	1.869	1.792	1.743	1.702
2016	3.003	2.740	2.514	2.327	2.251	2.190	2.132	2.070	1.987	1.910	1.831	1.782	1.740
2017	3.069	2.800	2.569	2.379	2.300	2.238	2.179	2.116	2.030	1.952	1.872	1.821	1.778
2018	3.137	2.862	2.625	2.431	2.351	2.287	2.227	2.162	2.075	1.995	1.913	1.861	1.817
2019	3.206	2.925	2.683	2.484	2.403	2.337	2.276	2.210	2.121	2.039	1.955	1.902	1.857
2020	3.276	2.987	2.742	2.539	2.456	2.389	2.326	2.258	2.167	2.084	1.998	1.944	1.898

ATTACHMENT 5
ANALOGOUS SYSTEM PRODUCTION DATA

PAVE TACK:

The PAVE TACK program includes 6 development units and 149 production units. The lot buys with the total lot cost are provide in the following table. Note, the dollars are in then year dollars, expressed in thousands.

EMD	FY81	FY82	FY83	FY84	TOTAL PROD
6	13	52	60	24	149
	$546	$439	$433	$190	

The Sharpshooter

The Sharpshooter program includes 4 development units and 200 production units. The lot buys with the average lot cost are provide in the following table. Note the dollars are in then year dollars, expressed in thousands.

EMD	FY83	FY84	FY85	FY86	FY87	TOTAL PROD
4	20	55	55	55	15	200
	$805	$595	$490	$435	$130	

Appendix J:

C-17 Case

COST ESTIMATING AT THE C-17 PROGRAM OFFICE

Prepared by:
Captain Kerrie G. Schieman
Captain James R. Passaro

SCENARIO

The C-17 System Program Office (SPO) is gearing up for its cost estimate to support a major acquisition milestone decision. Specifically, the C-17 program is approaching the milestone three production decision. Ms Gloria Himel is the Chief of the Formulation Section (YCFFA) for the C-17 Financial Management Division. She has called a much anticipated meeting for all her cost analysts to discuss the specific details of the impending estimating effort.

Captain Terry Vandergrift is one of 7 analysts (see atch 1) who crowded into Gloria's office for the meeting. Having just recently arrived at the program office, Terry was somewhat apprehensive about his first involvement with a major estimate. Terry's previous assignment was at the Air Force Institute of Technology, where he earned a Master's of Science in Cost Analysis. However, Terry had no previous acquisition experience. Gloria cleared her throat and began, "Alright everybody, we've only got three months to complete this estimate. I've looked at the past project you've all been working on, and I put together a roster that outlines what I expect each of you to accomplish for this estimate." Gloria passed out the roster to each analyst in the office (atch 2).

Terry immediately scanned the roster and began to ponder what approach he would need to employ to meet Gloria's schedule. Questions of data availability and possible points of contact began to fill his mind. But before any of these thoughts could solidify, Gloria interjected, "I probably don't need to remind you how much scrutiny last year's estimate received because of the cost growth. So be prepared to support your estimate in front of General Scott." With that the meeting was adjourned, but before Terry could get out the door Gloria stated, "Terry, hold on a minute I need to talk to you about your estimate." Terry quickly responded "sure", but inside he couldn't help but wonder what else was in store for him.

Gloria pulled a chair away from the conference table and took a seat across from Terry. "Terry, your portion of the estimate is definitely going to be a high-vis area. Last year it had the largest cost growth in the program, so it will definitely be an area of concern for OSD this year." Gloria continued, "We want to eliminate any doubts about the validity of your estimate. Mr Strobel (the program control chief) has requested you perform a cross-check estimate of your production sustaining engineering estimate. If you have any questions at all, let me know." Terry stood up and replied, "Thanks a lot Gloria. I'll get going with the research and get back to you if I have any questions."

C-17 PROGRAM BACKGROUND

ORGANIZATION

The C-17 program office was established in May of 1986. It is part of the Aeronautical Systems Center (ASC) located at Wright-Patterson AFB, Ohio. Provided below is an organizational chart of the program office.

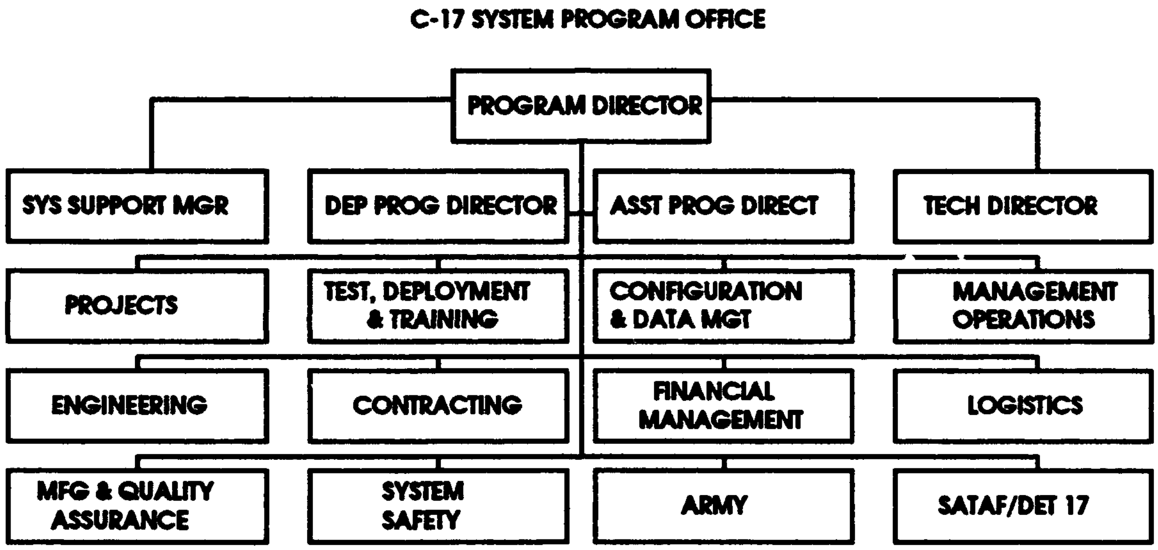


Figure 1

SYSTEM

The C-17A was developed to meet the force-projection requirements of the United States. It is a multi-engine turbofan heavy-lift, air refuelable cargo transport, designed to provide inter and intratheater airlift of all classes of military cargo, including outsize. It will be able to operate routinely in small, austere airfields (3,000 ft x 90 ft) previously restricted to C-130s, and will provide the first capability to airland or airdrop/extract outsize cargo in the tactical environment. Configuration variations will permit the aircraft to air deliver a variety of oversize combat and support equipment, including combat equipped troops, paratroopers, passengers, litters, pallets, 20-40 foot containers, and rolling stock, or varying combinations of each.

The C-17 will provide additional capability for rapid inter-theater deployment of combat forces and provide for the rapid mobility requirements of a modern Army within a theater of operation.

This aircaft is the first military transport to feature a full digital fly-by-wire control system and two-crew cockpit, with two full-time, all-function Heads-Up Displays (HUDs) and four multifunction electronic displays. Provided below is a summary of the major technical and operational characteristics of the C-17:

Characteristics

Length	174 feet
Height	55.1 feet
Wing Span	165 feet
Wing Sweep	25 degrees
Wing Area	3,800 square feet
Engines	4 Pratt & Whitney 2040s
Thrust Rating	40,700 lbs
Max Take-off Gross Weight	580,000 lbs
Max Payload	172,200 lbs
Cruise	.77 Mach

CONTRACT INFORMATION

McDonnell Douglas Corporation of Long Beach, California, was selected as the selected prime contractor in August 1981 and received a low-level research and development contract the following July. This was intended to cover C-17 technologies that would also benefit other airlift programs, while preserving the option to proceed to Engineering and Manufacturing Development (EMD) work on the C-17. EMD was approved in February 1985. Initial procurement funding was authorized in the FY 1990 budget, together with continued R&D. The contract is a Fixed Price Incentive Firm (FPIF) contract for development and two production options (lots 1 and 2). The contract has a 130% ceiling with an 80/20 share ratio and 13% fee.

Subcontractors for the C-17 program include Beech Aircraft Corporation (composite winglets), Delco Electronics Corporation (mission computer and electronic display system), Grumman Aircraft Systems (ailerons, rudder, and elevators), GEC Avionics (advanced heads-up display) LTV Aircraft Products (vertical and horizontal stabilizers, engine nacells), Honeywell Incorporated (support equipment and air data computers), Martin Marietta (tailcone), and GC Incorporated (electronic flight-control system).

CURRENT STATUS

The C-17 program is currently at the end of the EMD phase of the acquisition process. The C-17 made its first flight on September 15, 1991. The test program now includes five flight test aircraft (4 production units and 1 EMD unit) and two ground test articles (for static and durability testing). As of January 19, 1993, the five test aircraft had flown 267 missions for more than 930 hours. The program is now in initial operational testing and has accomplished many major test events, including aerial refueling, short-field landings, and formation flight. The C-17 has already established 14 new world records for payloads flown to specific altitudes for particular aircraft weight classes. Twelve production aircraft were funded between fiscal years 1990 and 1993. A total buy of 150 C-17s is currently planned.

ACQUISITION STRATEGY

The EMD schedule entailed producing three test articles: one for flight testing, one for static testing, and one for durability testing. Flight testing is being conducted at the Edwards AFB Flight Test Center. After completing flight testing, this article will be reconfigured for production. The static and durability articles were assembled on the production line, however, they are not fully produced aircrafts (no avionics, or inner guts to the plane). In other words, the static and durability articles were for ground testing only. The ground testing of these articles was performed at the McDonnell Douglas Plant. Illustrations of the static and durability articles undergoing testing are provided in attachments 3 and 4, respectively. The current production schedule is for 150 aircraft to be procured on a full funding basis over eleven years, beginning in FY90 and ending in FY2000. Provided below is the current buy schedule, followed by the delivery schedule.

	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02
BUY	2	2	4	4	6	12	24	24	24	24	24	-	-
DEL	-	-	-	5	4	6	12	24	24	24	24	24	3

The first four production aircraft will be configured and used as test aircraft. After the test program is completed, these test aircraft will be reconfigured as production aircraft and deployed.

RESEARCH EFFORT

After Gloria's meeting Terry returned to his desk and began looking over the responsibilities roster Gloria had given him earlier. He quickly outlined what he felt the major efforts for this estimate would be:

1) Estimate the EMD portion of sustaining engineering labor.
2) Estimate the production portion of sustaining engineering labor.
3) Perform a cross-check of the production sustaining engineering hours using an alternative methodology.
4) Evaluate the new Not to Exceed (NTE) contractor proposals (atch 5) to determine if the learning curve should be adjusted with a "rate" application. This evaluation will be based on the resulting statistics of the rate application.
5) Prepare a briefing to support the analysis and methodology (5-10 minutes).

Terry decided to use the above outline to guide his research efforts. He began with a visit to the C-17 Cost Branch files. There he found what he was looking for--a copy of last year's "Blue

Book" (annual estimate) documentation. He quickly located the EMD sustaining engineering section of the estimate, where he noted that an Estimate at Completion (EAC) approach had been used. The EAC demonstrated that EMD was 60% complete last year. Terry copied down the EAC formula that had been used.

$$EAC_{EMD} = ACWP_{cum} + \{(BAC - BCWP_{cum})/[(.25*SPI_{cum})+(.75*CPI_{cum})]\}$$

He then thumbed over to the production sustaining engineering section of the annual estimate. Last year's estimate seemed relatively straight forward--they had used the EMD sustaining engineering labor estimate as the T1 for the production sustaining engineering labor. In conducting his research he also noted that two significant issues had arisen over the last year: structural problems had caused numerous design changes, and the flight test program was extended, causing increased concurrency between EMD and Production. Terry then made copies of the pages he felt would be helpful and went back to his desk.

Terry's initial research efforts had paid off--he was beginning to feel more comfortable with the scope of this effort, but he still wasn't sure how to approach the cross-check of the production estimate. So he decided to do a little more research. He left his office and went across the base to the Aeronautical Systems Center Cost Library. There he was able to find several Component Cost Analyses (CCAs--formerly referred to as Independent Cost Estimates) that had been performed by various organizations in the past. Realizing that the purpose of a CCA is essentially to cross-check a program office estimate by using different cost-estimating methodologies, Terry felt these documents might reveal a feasible cross-check for his production engineering labor estimate.

In one of the CCAs he discovered that the Cost Agency had used an analogous methodology to estimate sustaining engineering labor. Specifically, the Cost Agency had used an in-house database they developed, called the Cost Estimating System (CES). This system collected Contractor Cost Data Report (CCDR) data from most of the aircraft in the Air Force inventory. He decided this could be quite useful in conducting his cross-check. He checked-out the CCA from the library and returned to the C-17 program office.

The next task in his cross-check effort involved conducting research devoted towards selecting appropriate analogous systems. His efforts resulted in the following list of systems: C-5A, C-130, KC-135, C-141, and B-1B. The CES database provided T1s and slopes (based on unit theory) for the sustaining engineering and recurring manufacturing hours for each system. The sustaining engineering hours/lb and recurring manufacturing hours/lb for each aircraft were derived by regressing the hours to develop the T1s and slopes provided in the following tables.

Sustaining Engineering (hrs/lb)

	B-1B	C-5A	C-130	C-141	KC-135
SLOPE	49.9%	67.2%	67.9%	70.3%	68.4%
T1(000)	3.11	2.97	3.88	1.52	2.3

Recurring Manufacturing (hrs/lb)

	B-1B	C-5A	C-130	C-141	KC-135
SLOPE	77.6%	73.9%	75.0%	76.4%	75.3%
T1(000)	19.34	15.58	16.99	12.54	15.69

He selected these aircraft based on their ability to represent varying age, complexity, size, and performance characteristics. The Cost Agency used the analogous program database to develop a cost estimating relationship (CER) of recurring engineering hours as a percentage of recurring manufacturing hours. This relationship was developed to show any effect on recurring engineering from changed manufacturing hours due to the introduction of composite materials. Terry noted that the number of production lots for each of the past programs varied from 5 to 8. Terry also collected the projected C-17 manufacturing hour spread from the cost analyst in charge of manufacturing (provided in the following table). Terry thought this could provide a good starting point to develop his production cross-check.

FY	90	91	92	93	94	95	96	97	98	99	00
MFG HRS	8.0	6.24	9.5	8.08	9.23	14.8	26.9	23.89	21.79	20.57	10.53

(hours expressed in millions)

Terry then turned to the task of the learning with rate analysis. Terry contacted the analyst who had worked this section last year, and was able to get a notebook that contained documentation on learning curves and rate adjustments. The documentation stated that because the C-17 program office is faced with the problem of estimating the impacts of many different quantity profiles with limited time and resources, a methodology was needed to better handle the task of quantifying the impacts of buy profile changes. The rate adjusted learning curve, which helps quantify the direct cost impact of changes in rate, incorporates a parameter for production rate directly into the learning curve equation (Q^R). The theory is the more units produced in a lot the lower the unit cost for that lot (the fixed costs are allocated over more units). Similar to a learning slope, a 95% rate slope will cause a 5% reduction in cost, solely due to rate effect, when production rate doubles. The addition of the Q^R factor better explains the variation in cost due to production rate changes.

Terry continued to read; in last year's annual estimate a 95% rate slope was selected (and was recommended for future estimates) after contractor data was run through the Learn Program with poor results. The 95% rate slope was chosen based on historical experience with similar aircraft. The documentation also stated that the rate adjustment is not always appropriate. Statistical analysis must be performed to support any decision to use or not use a rate adjustment. In addition to this documentation, Terry found a checklist that demonstrated how to incorporate learning with rate ($Y=AX^bQ^R$) in an electronic spreadsheet. Terry made a copy of the checklist for his own use (atch 6). Gloria informed Terry that he would not have to perform this analysis on all 300 of the subcontractors. Instead, he should only focus on the four subcontractors that have provided updated proposals. The learning slopes for the subcontractors who submitted NTEs are as follows: Kaspen Inc - 90%; Bancroft Corp - 97%; DBD Corp - 90%; CG Inc - 90%.

Armed with the previous research Terry then developed the following list of specific responsibilities.

1) Use the Report 42 (atch 7) to extract the design and general engineering hours needed to calculate the Tl EAC for EMD sustaining engineering labor. The hours will then be spread according to the time-phasing provided in attachment 8. The base year 81 EMD WRAP rate will be applied to the hours (atch 9). Complete the analyst input sheet (atch 10) to summarize the fiscal year costs and hours. OSD inflation indices are provided at attachment 11.

2) Use the total EMD hours (calculated from the EAC estimate) for the production sustaining engineering labor T1. A learning slope of 75.9% (unit curve) for sustaining engineering was provided by Douglas Aircraft. The base year 81 production WRAP rate (atch 9) will be applied to these hours. Complete the analyst input sheet to summarize the fiscal year costs and hours.

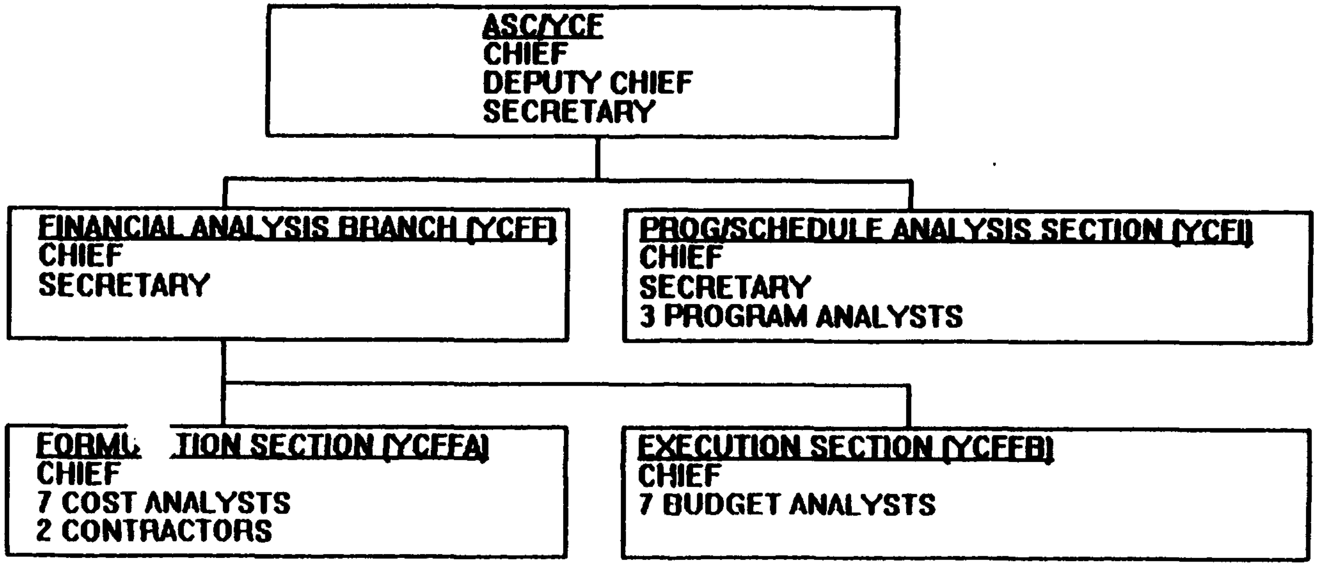
3) Use the CES T1s and slopes to perform the production sustaining engineering labor cross-check. Build a spreadsheet to compare the cross-check to the original estimate.

4) Use the checklist at attachment 6 (or other automated statistical package) to evaluate the contractor NTEs. The evaluation will be based on the resulting statistics from the statistical analysis. OSD inflation rates are provided at attachment 11. Provide a brief written summary of the results of this analysis.

5) Provide written documentation (3-4 pages) of the estimating process and attach all supporting documentation (spreadsheets, analyst input sheets, etc.,).

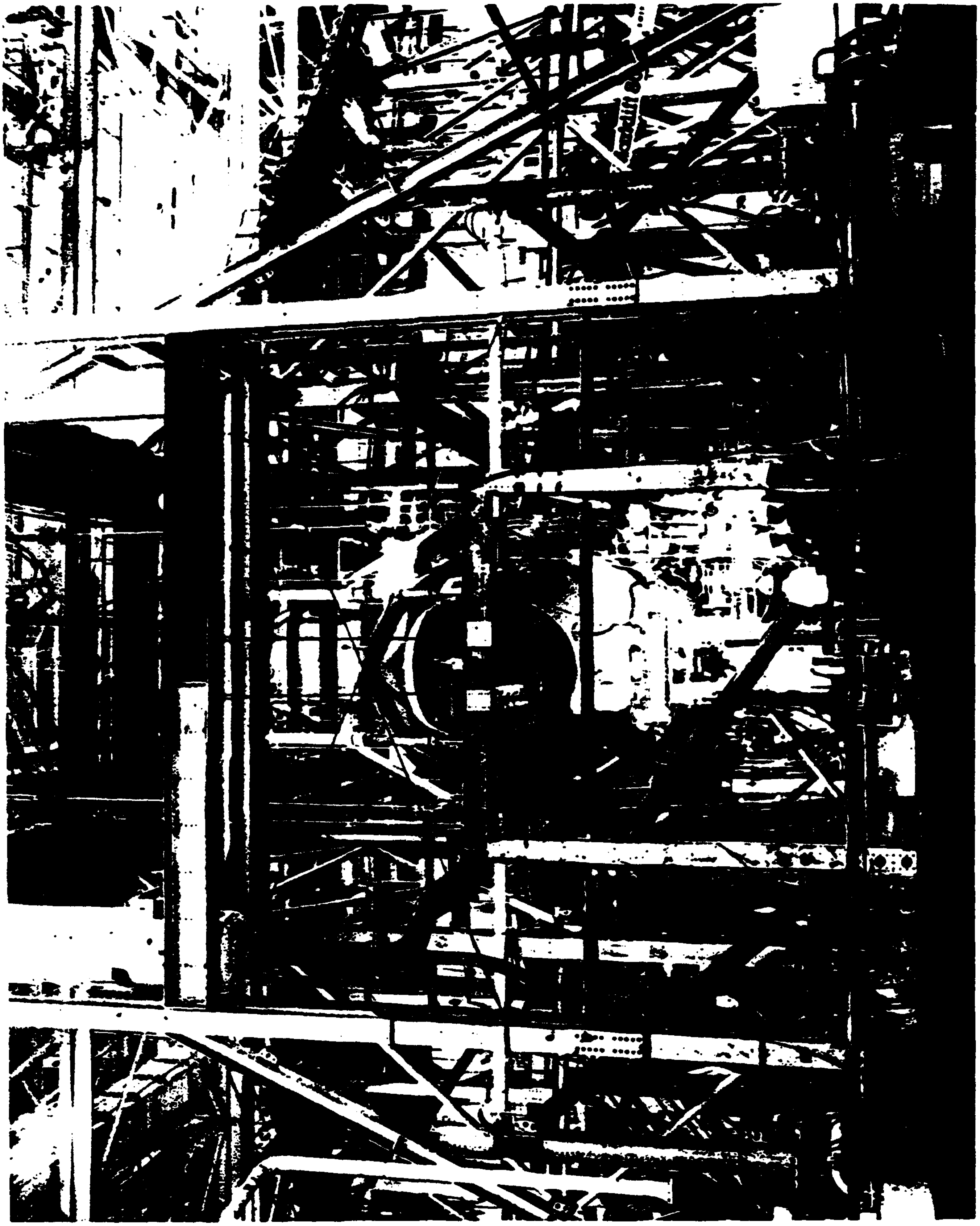
6) Prepare a breifing to support the analysis and methodology (5-10 minutes).

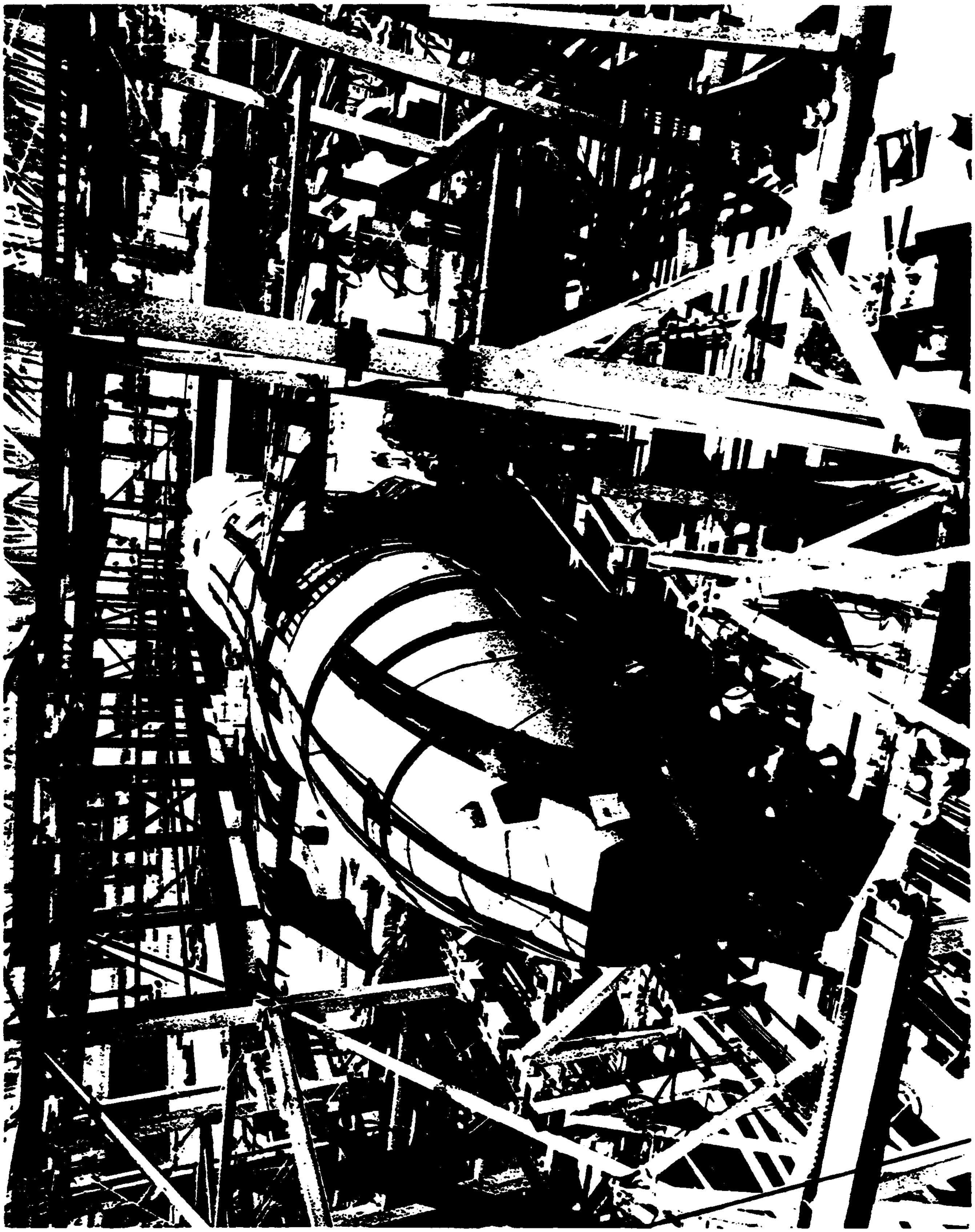
C-17 FINANCIAL MANAGEMENT DIVISION



C-17 COST BRANCH RESPONSIBILITIES

	GLORIA HIMEL	SAM JENKINS	TIM LEARY	TERRY VANDERGRIFT
Work Areas	Supervisor	Mfg Interface, Budget Interface-Prod, SAR (B)	SAR, FSD 1537, DAC CDRL focal pt, Test Interface Budget Interface-EMD	Engineering Interface - Journal voucher transfer, Rate/Learn Focal point
Annual Estimate	Integrate/Brief EMD & Prod tracks 2108 Summary	Mfg Labor, Mfg QA, Recurring Planning, Rate/Learn Sensitivity (B)	SE/PM (WBS 1061/1062), ST&E FSD 1537	Sustaining Engineering (1010, 1050), Rate/Learn Sensitivity
	TONY BENNET	**DOLLY SMARTON**	**AXIAL ROSE**	**KEVIN MITCHELL**
Work Areas	RFP/Prod focal pt Should Cost focal pt Schedule Interface, What-if prod model (B), Engine (B), IMIP/CRC/PRT ECP &CCP Evaluations	DAC Business/Fin analysis, Tooling Interface W/MFG, Retrofit Est focal point, What-If's/Prod 1537s, Training Interface, Production Model/Training Guide	CPR focal pt, Budget Interface-Exercises, What-ifs PSE, What-If's - Initial Spares, GE Price Interface, Prod Model (B), FPRP/FPRA/Wrap Rates/OH, EPA, DAC est SPO Est. Reconciliation	Cost Reduction Interface, Engine Interface, MYP & Exhibits, Mat'l Interface w/mfg, IMIP/CRC/PRT ECP & CCP evaluations (B)
Annual Estimate	Mission supt EMD & Prod, POL, Reconfig, IMIP, CRC's, PEP/PRT, FSD model Prod Model (B), Engine (B)	Non Recurring Planning and Tooling, Tooling QA, TACAN, SATCOM, ADS, GFE, ADV Buy, Business Base/Wrap rates (B), Balut OH Model (B)	Initial Spares, PSE, Data, OSA, Facilities, Warranty, ECO, ICS, Rpt 42/44, O&S focal point, MILCON focal pt, FSD model (B), Wrap Rates	RM/PP, Purchased Equipment, ICWO, Maj Subs, Avionics, Engine, Weight Tracks, Composite Factor, IMIP (B), CRC's (B), PEP/PRT (B)





Not To Exceed (NTE) Proposals

Contractor Name: Kaspen | **System Name:** Bulkheads | **Date:** 20 July 93

	Lot	Qty	Non-recurring $	Recurring $	Total Price TY$	Escalation	Total Price BY$	
EMD								
90	I	2						
91	II	2						
92	III	4						
93	IV	4	$0	$4.752	$4.752	1.06	$4.483	
94	V	6	0	6.333	6.333	1.13	5.604	
95	VI	12	0	11.870	11.870	1.20	9.892	
96	VII	24	0	23.561	23.561	1.28	18.407	
97	VIII	24	0	22.437	22.437	1.36	16.498	
98	IX	24	0	22.630	22.630	1.45	15.607	
99	X	24	0	23.220	23.220	1.56	14.885	
00	XI	24	0	23.010	23.010	1.68	13.696	

Note: Lots I-III are negotiated prices. Contractor escalation factors used.

Not To Exceed (NTE) Proposals

Contractor Name: Bancroft | **System Name:** Winglets | **Date:** 20 July 93

	Lot	Qty	Non-recurring $	Recurring $	Total Price TY$	Escalation	Total Price BY$	
EMD								
90	I	2						
91	II	2						
92	III	4						
93	IV	4	$0	$2.486	$2.486	1.11	$2.240	
94	V	6	0	3.371	3.371	1.19	2.833	
95	VI	12	0	6.777	6.777	1.25	5.422	
96	VII	24	0	13.550	13.550	1.31	10.344	
97	VIII	24	0	13.305	13.305	1.36	9.783	
98	IX	24	0	13.342	13.342	1.41	9.462	
99	X	24	0	13.570	13.570	1.47	9.231	
00	XI	24	0	13.720	13.720	1.53	8.967	

Note: Lots I-III are negotiated prices. Contractor escalation factors used.

Not To Exceed (NTE) Proposals

Contractor Name: DBD Corp. **System:** Main Landing Gear **Date:** 20 July 93

	Lot	Qty	Non-recurring $	Recurring $	Total Price TY$	Escalation	Total Price BY$	
EMD								
90	I	2						
91	II	2						
92	III	4						
93	IV	4	$0	$2.473	$2.473	1.07	$2.311	
94	V	6	0	3.710	3.710	1.15	3.226	
95	VI	12	0	8.756	8.756	1.23	7.118	
96	VII	24	0	22.766	22.766	1.46	15.593	
97	VIII	24	0	22.890	22.890	1.81	12.646	
98	IX	24	0	22.930	22.930	2.01	11.408	
99	X	24	0	23.050	23.050	2.23	10.336	
00	XI	24	0	23.252	23.252	2.50	9.301	

Note: Lots I-III are negotiated prices. Contractor escalation factors used.

Not To Exceed (NTE) Proposals

Contractor Name: CG Incorporated | **System Name:** Electronic Flt. Ctrl System | **Date:** 20 July 93

	Lot	Qty	Non-recurring $	Recurring $	Total Price TY$	Escalation	Total Price BY$	
EMD								
90	I	2						
91	II	2						
92	III	4						
93	IV	4	$.900	$6.300	$7.200	1.05	$6.857	
94	V	6	1.000	9.325	10.325	1.10	9.386	
95	VI	12	1.016	16.321	17.337	1.16	14.946	
96	VII	24	1.118	33.905	35.023	1.22	28.707	
97	VIII	24	1.174	34.153	35.327	1.28	27.599	
98	IX	24	1.185	34.230	35.415	1.34	26.429	
99	X	24	1.900	35.042	36.942	1.41	26.200	
00	XI	24	1.950	35.140	37.090	1.48	25.061	

Note: Lots I-III are negotiated prices. Contractor escalation factors used.

Rate Application

This guidance can be used to build a spreadsheet that will regress the lot midpoints versus the cost with a rate application, or without rate (in log space).

Step 1:

Calculate the True Lot Midpoint (TLM) for each lot, using the equation:

$$\left(\frac{(FirstUnit-.5)^{(b+1)}-(LastUnit+.5)^{(b+1)}}{(b+1)*(FirstUnit-LastUnit-1)}\right)^{\frac{1}{b}}$$

The b value is based on the learning slope for each specific contractor when calculating the TLMP. Often midpoints are calculated simply by adding the first and last units together and dividing the total by two (i.e. (first unit + last unit)/2). This method is referred to as the rule-of-thumb method. Rule-of-thumb midpoints may be sufficiently accurate for many cost analysis forecasts, but when a greater degree of accuracy is required, true lot midpoints (TLMs) can be used. True lot midpoints were used in the C-17 estimate due to the high visibility of the program and the resulting need for precision.

Step 2:

Take the Log of the True Lot Midpoint for each lot.

Step 3:

Extract the Then Year dollars (TY$) for each lot from the Not To Exceed (NTE) Proposals.

Step 4:

Deflate the contractor's TY$ using OSD Weighted Inflation rates to obtain an FY81 Base Year dollar.

Step 5:

Derive the Average Unit Cost of each lot (Base Year$/Lot Quantity).

Step 6:

Calculate Q^r: Where Q is the quantity of the lot, and r is the log of the rate slope divided by the log of 2.

Step 7:

To incorporate rate into the regression analysis, you must first normalize the unit cost by the Q^r. This can be done with the following equation.

$$\frac{UnitCost}{Q^r}$$

Normalizing the unit cost in this manner eliminates the potential for multicollinearity between the rate quantity (Q) and the lot quantity (X) in the equation $Y=AX^bQ^r$. The normalized regression equation then becomes $Y/Q^r = AX^b$.

Step 8:

Take the log of the $\frac{UnitCost}{Q^r}$ and the log of the Unit Cost (not normalized).

Step 9:

The next step is to regress the log unit costs (with and without rate) against the log of the True Lot Midpoints (X). For example, you will regress Y versus X (without rate) and Y/Q^r versus X (with rate).

Step 10:

Analyze the resulting statistics and determine if rate is applicable for the cost element.

WBS DEFINITIONS AND ACRONYMS

Engineering:

a. **Direct Labor Hours** - The hours expended in the study, analysis, design, development, evaluation, and redesign of the specified reporting element. Includes the preparation of specifications, drawings, parts lists, wiring diagrams, technical coordination between engineering and manufacturing, vendor coordination, test planning and scheduling, analysis of test results, data reduction, and report preparation. This also includes the determination and specification of requirements for reliability, maintainability and quality control.

b. **Direct Labor Dollars** - The actual engineering direct labor dollars expressed as the incurred composite dollar rates per hour times the direct labor hours. For projections the composite dollar rates will be developed in accordance with accepted accounting practices. Shift premiums and overtime premiums will be shown under other direct charges.

c. **Overhead** - The proportionate part of indirect engineering expenses properly chargeable for the specified reporting element.

d. **Material** - The cost of raw material, and purchased parts (e.g., printed circuit boards) evaluated or consumed in the performance of the engineering function for the specified reporting element. Also included is engineering test equipment, i.e., oscilloscopes, transducers, recorders, radio transmitters, converters, discriminators, receivers, and similar equipment required to accomplish the engineering function for the specified reporting element. Included is the applicable costs of special test equipment as defined in ASPR 15-205, 40(b), (c) and (d).

e. **Other Direct Charges** - The costs of travel, per diem, shift premiums, overtime premiums, automatic data processing, reproduction of printed material, and rental of special test facilities, and equipment and other engineering items not allocated to the categories of direct labor, overhead and material for the specific reporting element.

f. **Total** - The sum of the dollars for engineering direct labor, overhead, material, and other direct charges (excluding G&A and profit)

Note: the categories (c-e) are included in the composite wrap rate given by the appropriate analyst.

Sustaining Engineering EMD: Covers all of the engineering labor within the DAC engineering functions of design and general engineering for the air vehicle (wbs element 1010) and system test and evaluation (wbs element 1050) in the Cost Performance Report. Within the function of design engineering the following effort is accomplished: structural and mechanical design, component test requirements, equipment installation design, technical analysis, preparation of procurement specifications, subcontractor/vendor liaison associated with design, test and fabrication programs, liaison with the customer and support of manufacturing.

Sustaining Engineering - Production: Involves effort associated with administration, change evaluation and liaison with the customer, vendors, manufacturing, quality assurance, product support and material. Typically, sustaining engineering also involves analysis and incorporation of changes, materials and process specification and reliability activities. These activities are not explicitly accounted for within the function of sustaining engineering on this program. Within WBS 1010, the functions of Flight Controls, Product Definition, Product Center Operations, Aircraft Performance, Avionics Integration and Integrated Logistics Support make up the sustaining engineering effort.

LEGEND

LBR ASY HRS - Assembly Direct Labor Hours (DLH) for Manufacturing.
LBR FAB HRS - Fabrication DLHs for Manufacturing.
LBR IE HRS - Industrial Engineering DLHs for Manufacturing.
LBR PLG HRS - Planning DLHs for Manufacturing.
LBR QA HRS - Quality Assurance DLHs for Manufacturing
LBR TLG HRS - Tooling DLHs.
LBR DES HRS - Design Engineering Hours.
LBR GEN HRS - General Engineering Hours.
LBR MC HRS - Mission Computer DLHs.
LBR FAC HRS - Facilities DLHs.
LBR SFC HRS - Shop Floor Control DLHs.
LBR UNA HRS - Unaccounted for Actual DLHs.
LBR MIS HRS - Management Information System DLHs.
LBR REL HRS - Materials Release DLHs.
LBR STR HRS - STORES DLHs.

BUS PLNG - Business Planning
FLT CTRLS - Flight Controls
PROD DEFIN - Product Definition
PCO - Product Center Operations
FLT TEST - Flight Test
A\C PERFOR - Aircraft Performance
SUPP MGMT - Supplier Management
QA - Quality Assurance
AVION INTEG - Avionics Integration
ILS - Integrated Logistics Support

REPORT WBSSD
PROGRAM C-17 EMD
SEGMENT 1
WBS GOVT/DAC 1010/1000

WBS HOUR REPORT BY SUB-DIVISION
AIR VEHICLE (1010)

PAGE 1
ACCOUNTING PERIOD OCT 9X

	CURRENT PERIOD					CUMULATIVE TO DATE					AT COMPLETION		
	BCWS	BCWP	ACWP	SCH VAR	CST VAR	BCWS	BCWP	ACWP	SCH VAR	CST VAR	BAC	EAC	VAC
A)PRODUCTION													
LBR ASY HRS	-5615	0	244	5615	-244	225615	232615	578000	7000	-345385	225615	582026	-356410
LBR IE HRS	-218	0	0	218	0	10167	9692	20474	-474	-10782	10167	20577	-10410
LBR PLG HRS	0	0	13	0	-13	84487	84487	113795	0	-29308	84487	117449	-32962
LBR SFC HRS	0	0	26	0	-26	10487	10538	36962	51	-26423	10487	37090	-26603
LBR TLG HRS	5885	12744	2808	6859	9936	895526	876026	1847346	-19500	-971321	907654	1852333	-944679
LBR UNA HRS	0	0	28218	0	-28218	0	0	28218	0	-28218	0	28218	-28218
TOTAL LBR HRS	51	12744	31308	12692	-18564	1226282	1213359	2624795	-12923	-1411436	1238410	2637692	-1399282
													0
B)BUS PLNG													
LBR UNA HRS	0	0	13	0	-13	0	0	13	0	-13	0	13	-13
D)FLT CTRLS													
LBR DES HRS	45	45	46	0	-1	2918	2918	2728	0	190	3354	2967	387
LBR GEN HRS	33	0	0	-33	0	186	186	135	0	51	186	135	51
LBR UNA HRS	0	0	769	0	-769	0	0	769	0	-769	0	769	-769
TOTAL LBR HRS	78	45	815	-33	-771	3104	3104	3632	0	-528	3540	3871	-331
A)PROD DEFIN													
LBR ASY HRS	0	0	154	0	-154	185513	185513	246192	0	-60679	185513	246192	-60679
LBR GEN HRS	68	41	46	-27	-5	12237	11735	16596	-503	-4862	13835	17119	-3285
LBR DES HRS	242	253	587	10	-335	196827	196805	196821	-22	-15	198665	197382	1283
LBR IE HRS	0	0	0	0	0	9769	9397	5167	-372	4231	9769	5192	4577
LBR MC HRS	0	0	0	0	0	167	167	0	0	167	167	0	167
LBR MIS HRS	0	0	0	0	0	51	51	231	0	-179	51	231	-179
LBR REL HRS	0	0	0	0	0	20231	20231	21410	0	-1179	20231	21410	-1179
LBR SFC HRS	0	0	0	0	0	6603	6603	8705	0	-2103	6603	8705	-2103
LBR STR HRS	0	0	0	0	0	1667	1667	103	0	1564	1667	103	1564
LBR TLG HRS	0	0	641	0	-641	2026	2026	28974	0	-26949	2026	28974	-26949
LBR UNA HRS	0	0	12282	0	-12282	0	0	12282	0	-12282	0	12282	-12282
TOTAL LBR HRS	310	294	13710	-17	-13417	435090	434194	536481	-896	-102287	438526	537591	-99065

REPORT	WBSSD		
PROGRAM	C-17 EMD	WBS HOUR REPORT BY SUB-DIVISION	PAGE 2
SEGMENT	1	AIR VEHICLE (1010)	ACCOUNTING PERIOD OCT 9X
WBS GOVT/DAC	1010/1000		

	CURRENT PERIOD					CUMULATIVE TO DATE					AT COMPLETION		
	BCWS	BCWP	ACWP	SCH VA	CST VA	BCWS	BCWP	ACWP	SCH VA	CST VAR	BAC	EAC	VAC
F)PCO													
LBR ASY HRS	0	0	0	0	0	20346	16090	20897	-4256	-4808	20346	21744	-1397
LBR DES HRS	0	0	133	0	-133	205	205	733	0	-528	205	756	-551
LBR FAB HRS	13	487	936	474	-449	119333	120782	144500	1449	-23718	119423	147808	-28385
LBR FAC HRS	0	0	0	0	0	6359	6359	4397	0	1962	6359	4667	1692
LBR IE HRS	0	13	26	13	-13	8705	8231	10667	-474	-2436	8718	10679	-1962
LBR MC HRS	0	0	0	0	0	205	205	103	0	103	205	103	103
LBR MIS HRS	0	0	0	0	0	2269	2244	2936	-26	-692	2269	2936	-667
LBR PLG HRS	0	0	77	0	-77	654	654	2295	0	-1641	654	2295	-1641
LBR QA HRS	0	26	141	26	-115	23795	23833	47910	38	-24077	23795	48846	-25051
LBR REL HRS	0	0	205	0	-205	34949	34949	36821	0	-1872	34949	37051	-2103
LBR SFC HRS	0	51	90	51	-38	13256	13179	20910	-77	-7731	13269	21231	-7962
LBR STR HRS	13	141	128	128	13	29628	30705	43705	1077	-13000	29769	45064	-15295
LBR TLG HRS	0	0	1897	0	-1897	334026	332372	926538	-1654	-594167	334026	941167	-607141
LBR UNA HRS	0	0	21808	0	-21808	0	0	21808	0	-21808	0	21808	-21808
									0	0			0
TOTAL LBR HRS	26	718	25441	692	-24723	593731	589808	1284221	-3923	-694413	593987	1306154	-712167
G)FLT TEST													
LBR GEN HRS	27	12	0	-15	12	37	22	10	-15	12	788	429	359
L)A/C PERFOR													
LBR DES HRS	205	126	49	-79	77	2103	2023	1254	-79	769	3715	1814	1901
LBR GEN HRS	-65	0	17	65	-17	1641	1621	2740	-21	-1119	1647	2740	-1092
LBR UNA HRS	0	0	38	0	-38	0	0	38	0	-38	0	38	-38
TOTAL LBR HRS	140	126	104	-14	22	3744	3644	4032	-100	-388	5363	4592	771
M)SUPP MGMT													
LBR MC HRS	0	0	0	0	0	962	962	77	0	885	962	77	885
Q)QA													
LBR QA HRS	410	718	3628	308	-2910	142346	139282	268231	-3064	-128949	143218	275577	-132359
LBR UNA HRS	0	0	4897	0	-4897	0	0	4897	0	-4897	0	4897	-4897
TOTAL LBR HRS	410	718	8526	308	-7808	142346	139282	273128	-3064	-133846	143218	280474	-137256
R)AVION INTEG													
LBR DES HRS	28	28	192	0	-164	17605	17605	16846	0	759	18129	17541	588
LBR GEN HRS	0	0	0	0	0	3013	3013	4769	0	-1756	3013	4769	-1756
LBR UNA HRS	0	0	667	0	-667	0	0	667	0	-667	0	667	-667
TOTAL LBR HRS	28	28	859	0	-831	20618	20618	22282	0	-1664	21142	22977	-1835

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REPORT WBSSD
PROGRAM C-17 EMD
SEGMENT 1
WBS GOVT/DAC 1010/1000

WBS HOUR REPORT BY SUB-DIVISION
AIR VEHICLE (1010)

PAGE 3
ACCOUNTING PERIOD OCT 9X

	CURRENT PERIOD					CUMULATIVE TO DATE					AT COMPLETION		
	BCWS	BCWP	ACWP	SCH VA	CST VA	BCWS	BCWP	ACWP	SCH VA	CST VAR	BAC	EAC	VAC
SHLS													
LBR PS HRS	0	0	0	0	0	51	51	38	0	13	51	38	13
LBR UNA HRS	0	0	1923	0	-1923	0	0	1923	0	-1923	0	1923	-1923

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REPORT WBSSD — WBS HOURS REPORT BY SUB-DIVISION — PAGE 1

PROGRAM :C-17 EMD — SYSTEM TEST AND EVALUATION (1050) — ACCOUNTING PE OCT 9X

SEGMENT :1

WBS GOVT/DAC 1050/4000

	CURRENT PERIOD					CUMULATIVE TO DATE					AT COMPLETION		
	BCWS	BCWP	ACWP	SCH VA	COST V	BCWS	BCWP	ACWP	SCH VA	COST V	BAC	BAC	VAC
A)PRODUCTION													
LBR ASY HRS	765	14078	14373	13314	-294	242843	223176	518804	-19667	-295627	242843	568314	-325471
LBR IE HRS	39	569	216	529	353	10255	8961	11784	-1294	-2824	10255	12882	-2627
LBR PLG HRS	0	0	431	0	-431	12510	12510	13451	0	-941	12510	15569	-3059
LBR SFC HRS	39	627	569	588	59	10804	9745	25667	-1059	-15922	10804	28451	-17647
LBR TLG HRS	0	0	0	0	0	19294	19294	17431	0	1863	19294	17431	1863
LBR UNA HRS	0	0	2078	0	-2078	0	0	2078	0	-2078	0	2078	-2078
TOTAL LBR HRS	843	15275	17667	14431	-2392	295706	273686	589216	-22020	-315529	295706	644725	-349020
B)BUS PLNG													
LBR UNA HRS	0	0	0	0	0	0	0	0	0	0	0	0	0
D)FLT CTRL													
LBR DES HRS	112	131	194	20	-63	2590	2133	2847	-457	-714	3653	4067	-414
LBR GEN HRS	0	10	0	10	10	1420	1422	1200	2	222	1786	1296	250
LBR UNA HRS	0	0	20	0	-20	0	0	20	0	-20	0	20	-20
TOTAL LBR HRS	112	141	214	29	-73	4010	3555	4067	-455	-512	5439	5382	57
E)PROD DEF													
LBR ASY HRS	0	0	118	0	-118	70059	70059	79647	0	-9588	70059	79647	-9588
LBR DES HRS	76	76	100	0	-24	14157	14157	16839	0	-2682	15261	17582	-2322
LBR GEN HRS	1829	1171	2075	-659	-904	40477	35583	42962	-4894	-7379	51699	47514	4185
LBR IE HRS	0	0	0	0	0	2490	2490	2294	0	196	2490	2294	196
LBR MC HRS	0	0	0	0	0	20	20	0	0	20	20	0	20
LBR MIS HRS	0	0	0	0	0	882	882	1255	0	-373	882	1255	-373
LBR SFC HRS	0	0	0	0	0	1294	1294	1000	0	294	1294	1000	294
LBR STR HRS	0	0	0	0	0	137	137	98	0	39	137	98	39
LBR UNA HRS	0	0	9588	0	-9588	0	0	9588	0	-9588	0	9588	-9588
TOTAL LBR HRS	1906	1247	11880	-659	-10633	129516	124623	153684	-4894	-29061	141842	158979	-17137

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REPORT	WBSSD	WBS HOURS REPORT BY SUB-DIVISION	PAGE 2
PROGRAM	:C-17 BMD	SYSTEM TEST AND EVALUATION (1050)	ACCOUNTING PE OCT 9X
SEGMENT	:1		
WBS GOVT/DAC: 1050/4000			

	CURRENT PERIOD					CUMULATIVE TO DATE					AT COMPLETION		
	BCWS	BCWP	ACWP	SCH VA	COST V	BCWS	BCWP	ACWP	SCH VA	COST V	BAC	BAC	VAC
F)PCO													
LBR ASY HRS	0	0	0	0	0	22176	13706	21725	-8471	-8020	22176	34471	-12294
LBR FAB HRS	255	1078	765	824	314	195980	195412	86255	-569	109157	198255	88627	5591
LBR FAC HRS	0	0	0	0	0	294	294	235	0	59	294	235	59
LBR IE HRS	0	20	0	20	20	7784	6529	2824	-1255	3706	7843	3059	244
LBR MC HRS	0	0	0	0	0	59	59	59	0	0	59	59	0
LBR MIS HRS	0	0	0	0	0	2961	1745	3667	-1216	-1922	2961	4765	-1804
LBR PLG HRS	0	0	0	0	0	3412	3412	471	0	2941	3412	471	2941
LBR QA HRS	20	-78	78	-98	-157	14647	13529	10549	-1118	2980	14745	13157	1588
LBR SFC HRS	39	137	98	98	39	21098	20490	10784	-608	9706	21333	10961	10373
LBR STR HRS	0	451	294	451	157	20961	20882	23647	-78	-2765	21020	24059	-3039
LBR TLG HRS	0	0	39	0	-39	10588	10588	10980	0	-392	10588	10980	-392
LBR UNA HRS	0	0	1706	0	-1706	0	0	1706	0	-1706	0	1706	-1706
TOTAL LBR HRS	314	1608	2980	1294	-1373	299961	286647	172902	-13314	113745	302686	192549	110137
G)FLT TEST													
LBR GEN HRS	2067	773	2980	-1294	-2208	36801	33379	45497	-3422	-12118	59892	62353	-2461
LBR UNA HRS	0	0	1196	0	-1196	0	0	1196	0	-1196	0	1196	-1196
TOTAL LBR HRS	2067	773	4176	-1294	-3404	36801	33379	46693	-3422	-13314	59892	63549	-3657
L)ACFT PERF													
LBR DES HRS	382	163	25	-220	137	776	557	163	-220	394	924	335	588
LBR GEN HRS	-249	0	49	249	-49	8492	8492	13424	0	-4931	8492	13424	-4931
TOTAL LBR HRS	133	163	75	29	88	9269	9049	13586	-220	-4537	9416	13759	-4343
M) SUP MGT													
LBR MC HRS	0	0	0	0	0	176	176	78	0	98	176	78	98
Q)QA													
LBR QA HRS	98	2118	4098	2020	-1980	49235	45980	54137	-3255	-8157	49235	58451	-9216
LBR UNA HRS	0	0	333	0	-333	0	0	333	0	-333	0	333	-333
TOTAL LBR HRS	98	2118	4431	2020	-2314	49235	45980	54471	-3255	-8490	49235	58784	-9549

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REPORT	WBSSD	WBS HOURS REPORT BY SUB-DIVISION	PAGE 3
PROGRAM	:C-17 BMD	SYSTEM TEST AND EVALUATION (1050)	ACCOUNTING PE OCT 9X
SEGMENT	:1		
WBS GOVT/DAC: 1050/4000			

	CURRENT PERIOD					CUMULATIVE TO DATE					AT COMPLETION		
	BCWS	BCWP	ACWP	SCH VA	COST V	BCWS	BCWP	ACWP	SCH VA	COST V	BAC	EAC	VAC
R)AVION INT													
LBR DES HRS	494	335	276	-159	59	6725	5200	7678	-1525	-2478	11233	10104	1129
LBR GEN HRS	-12	0	4	12	-4	2712	2712	2439	0	273	2712	2439	273
LBR UNA HRS	0	0	20	0	-20	0	0	20	0	-20	0	20	-20
TOTAL LBR HRS	246	171	144	-75	27	4813	4034	5161	-779	-1127	7111	6398	713
S)ILS													
LBR PS HRS	392	392	392	0	0	6412	6412	8216	0	-1804	13176	14961	-1784
LBR UNA HRS	0	0	255	0	-255	0	0	255	0	-255	0	255	-255
TOTAL LBR HRS	20	20	33	0	-13	327	327	432	0	-105	672	776	-104

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FISCAL YEAR PERCENTAGE SPREADS

	FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FY93	TOTAL
Manufacturing	1	1	2	4	14	59	19	0	0	0	100
Tooling	1	1	17	20	15	20	22	4	0	0	100
Quality Assurance	1	1	17	20	15	20	23	3	0	0	100
Engineering	1	14	15	25	22	15	5	3	0	0	100
Avionics	1	1	5	5	29	41	17	1	0	0	100
ICWOs	1	2	8	21	24	25	16	1	2	0	100
Flight Test	2	2	4	8	15	30	32	7	0	0	100
Lab Test	13	7	12	19	23	15	7	3	1	0	100
Major Subcontractor	1	2	8	21	24	25	16	1	2	0	100

EMD WRAP RATE SUMMARY

Development Rates

		FY81	FY[illegible]	FY83	FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FY93
Manufacturing	BY $	31.35	32[illegible]	31.23	28.92	30.37	33.19	34.37	34.31	35.75	35.75	35.75	35.75	35.75
	TY $	43.04	4[illegible]	44.44	48.17	54.37	58.15	59.94	59.94	64.45	68.63	70.85	73.12	75.48
Engineering	BY$	41.29	40.8[illegible]	41.89	40.85	42.98	46.64	48.06	49.76	51.78	51.78	51.78	51.78	51.78
	TY$	56.68	58.37	61.91	62.79	68.16	76.39	81.37	85.47	92.32	96.32	99.37	102.58	102.58
Tooling/Plan	BY$	37.30	38.57	37.88	37.85	37.48	41.39	44.69	46.06	47.08	49.17	49.17	49.17	49.17
	TY$	51.21	55.16	55.58	57.58	65.64	73.20	77.92	82.24	88.65	91.50	94.40	97.45	100.56
Quality/Assur	BY$	35.22	36.24	36.58	33.82	35.28	38.13	39.44	39.12	39.12	40.50	40.50	40.50	40.50
	TY$	48.37	51.86	54.08	51.98	55.95	62.41	66.42	68.75	73.02	75.35	77.56	80.27	82.84

Production Rates

		FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00
Manufacturing	BY $	28.25	28.06	32.20	34.01	35.41	36.10	36.52	37.05	37.12	37.12	37.12
	TY $	44.70	45.99	54.55	59.45	64.10	67.45	70.75	73.36	76.28	78.28	81.25
Engineering	BY$	38.15	39.15	45.25	48.25	50.85	51.90	53.12	53.71	53.81	53.87	53.81
	TY$	60.36	63.90	76.47	84.54	91.03	96.91	102.48	106.94	110.58	115.62	118.85
Tooling/Plan	BY$	35.15	36.22	42.98	46.08	47.97	49.26	50.35	50.98	51.06	51.09	51.09
	TY$	55.61	59.36	72.67	80.73	86.83	92.06	97.53	101.46	104.92	108.52	113.43
Quality/Assur	BY$	32.64	36.27	36.85	33.82	35.28	38.13	39.58	40.50	40.50	40.50	40.50
	TY$	51.64	53.49	63.14	68.73	73.05	77.58	80.45	83.75	86.43	89.19	92.05

COST ANALYST INPUT SHEET

C-17 PROGRAM

ANALYST NAME: **DATE:**

WBS ELEMENT/NUMBER:

DEVELOPMENT ESTIMATE

BRIEF DESCRIPTION:

($ and hours in 000)

	FY81	FY82	FY83	FY84	FY85	FY85
BY 81$						
HOURS						

	FY87	FY88	FY89	FY90	FY91	FY92	FY93
BY 81$							
HOURS							

COST ANALYST INPUT SHEET

C-17 PROGRAM

ANALYST NAME: **DATE:**

WBS ELEMENT/NUMBER:

PRODUCTION ESTIMATE

BRIEF DESCRIPTION:

($ and hours in 000)

	FY90	FY91	FY92	FY93	FY94	FY95
BY 81$						
HOURS						

	FY96	FY97	FY98	FY99	FY00
BY 81$					
HOURS					

** RAW **   AIRCRAFT PROCUREMENT (3010)   OSD RATES   MARCH 1993

FISCAL YEAR	BASE YEAR 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.000	0.912	0.837	0.775	0.750	0.729	0.710	0.689	0.662	0.636	0.610	0.593	0.579
1982	1.096	1.000	0.917	0.849	0.822	0.799	0.778	0.755	0.725	0.697	0.668	0.650	0.635
1983	1.195	1.090	1.000	0.926	0.895	0.871	0.848	0.823	0.790	0.760	0.729	0.709	0.692
1984	1.290	1.177	1.080	1.000	0.967	0.941	0.916	0.889	0.854	0.821	0.787	0.765	0.747
1985	1.334	1.217	1.117	1.034	1.000	0.973	0.947	0.920	0.883	0.849	0.814	0.791	0.773
1986	1.371	1.251	1.148	1.063	1.028	1.000	0.974	0.945	0.907	0.872	0.836	0.814	0.795
1987	1.408	1.285	1.179	1.092	1.056	1.027	1.000	0.971	0.932	0.896	0.859	0.836	0.816
1988	1.451	1.324	1.214	1.124	1.087	1.058	1.030	1.000	0.960	0.923	0.885	0.861	0.840
1989	1.512	1.379	1.265	1.172	1.133	1.102	1.073	1.042	1.000	0.962	0.922	0.897	0.876
1990	1.572	1.434	1.316	1.218	1.178	1.146	1.116	1.084	1.040	1.000	0.959	0.933	0.911
1991	1.640	1.496	1.373	1.271	1.229	1.196	1.164	1.130	1.085	1.043	1.000	0.973	0.950
1992	1.686	1.538	1.411	1.306	1.264	1.229	1.197	1.162	1.115	1.072	1.028	1.000	0.977
1993	1.726	1.575	1.445	1.338	1.294	1.259	1.226	1.190	1.142	1.098	1.053	1.024	1.000
1994	1.768	1.613	1.480	1.370	1.325	1.289	1.255	1.218	1.169	1.124	1.078	1.049	1.024
1995	1.808	1.650	1.514	1.401	1.355	1.318	1.284	1.246	1.196	1.150	1.103	1.073	1.048
1996	1.850	1.688	1.548	1.434	1.387	1.349	1.313	1.275	1.224	1.177	1.128	1.097	1.072
1997	1.890	1.725	1.582	1.465	1.417	1.378	1.342	1.303	1.251	1.202	1.153	1.122	1.095
1998	1.932	1.763	1.617	1.497	1.448	1.409	1.372	1.332	1.278	1.229	1.178	1.146	1.119
1999	1.975	1.802	1.653	1.530	1.480	1.440	1.402	1.361	1.306	1.256	1.204	1.171	1.144
2000	2.018	1.841	1.689	1.564	1.513	1.471	1.433	1.391	1.335	1.284	1.231	1.197	1.169
2001	2.062	1.882	1.726	1.598	1.546	1.504	1.464	1.422	1.364	1.312	1.258	1.224	1.195
2002	2.108	1.923	1.764	1.634	1.580	1.537	1.496	1.453	1.394	1.341	1.285	1.250	1.221
2003	2.154	1.965	1.803	1.670	1.615	1.571	1.529	1.485	1.425	1.370	1.314	1.278	1.248
2004	2.202	2.009	1.843	1.706	1.650	1.605	1.563	1.518	1.456	1.400	1.343	1.306	1.275
2005	2.250	2.053	1.883	1.744	1.687	1.641	1.597	1.551	1.488	1.431	1.372	1.335	1.303
2006	2.299	2.098	1.925	1.782	1.724	1.677	1.633	1.585	1.521	1.463	1.402	1.364	1.332
2007	2.350	2.144	1.967	1.821	1.762	1.714	1.669	1.620	1.555	1.495	1.433	1.394	1.361
2008	2.402	2.191	2.010	1.861	1.800	1.751	1.705	1.656	1.589	1.528	1.465	1.425	1.391
2009	2.455	2.240	2.055	1.902	1.840	1.790	1.743	1.692	1.624	1.561	1.497	1.456	1.422
2010	2.509	2.289	2.100	1.944	1.880	1.829	1.781	1.729	1.659	1.596	1.530	1.488	1.453
2011	2.564	2.339	2.146	1.987	1.922	1.869	1.820	1.767	1.696	1.631	1.564	1.521	1.485
2012	2.620	2.391	2.193	2.031	1.964	1.911	1.860	1.806	1.733	1.667	1.598	1.554	1.518
2013	2.678	2.443	2.242	2.075	2.007	1.953	1.901	1.846	1.771	1.703	1.633	1.589	1.551
2014	2.737	2.497	2.291	2.121	2.051	1.996	1.943	1.886	1.810	1.741	1.669	1.624	1.586
2015	2.797	2.552	2.341	2.168	2.097	2.039	1.986	1.928	1.850	1.779	1.706	1.659	1.620
2016	2.858	2.608	2.393	2.215	2.143	2.084	2.029	1.970	1.891	1.818	1.743	1.696	1.656
2017	2.921	2.665	2.445	2.264	2.190	2.130	2.074	2.014	1.933	1.858	1.782	1.733	1.692
2018	2.986	2.724	2.499	2.314	2.238	2.177	2.120	2.058	1.975	1.899	1.821	1.771	1.730
2019	3.051	2.784	2.554	2.365	2.287	2.225	2.166	2.103	2.019	1.941	1.861	1.810	1.768
2020	3.118	2.845	2.610	2.417	2.338	2.274	2.214	2.150	2.063	1.984	1.902	1.850	1.807
2021	3.187	2.908	2.668	2.470	2.389	2.324	2.263	2.197	2.108	2.027	1.944	1.891	1.846
2022	3.257	2.972	2.726	2.524	2.441	2.375	2.313	2.245	2.155	2.072	1.986	1.932	1.887
2023	3.329	3.037	2.786	2.580	2.495	2.427	2.363	2.295	2.202	2.117	2.030	1.975	1.929
2024	3.402	3.104	2.848	2.637	2.550	2.481	2.415	2.345	2.251	2.164	2.075	2.018	1.971
2025	3.477	3.172	2.910	2.695	2.606	2.535	2.469	2.397	2.300	2.212	2.120	2.063	2.014
2026	3.553	3.242	2.974	2.754	2.664	2.591	2.523	2.449	2.351	2.260	2.167	2.108	2.059

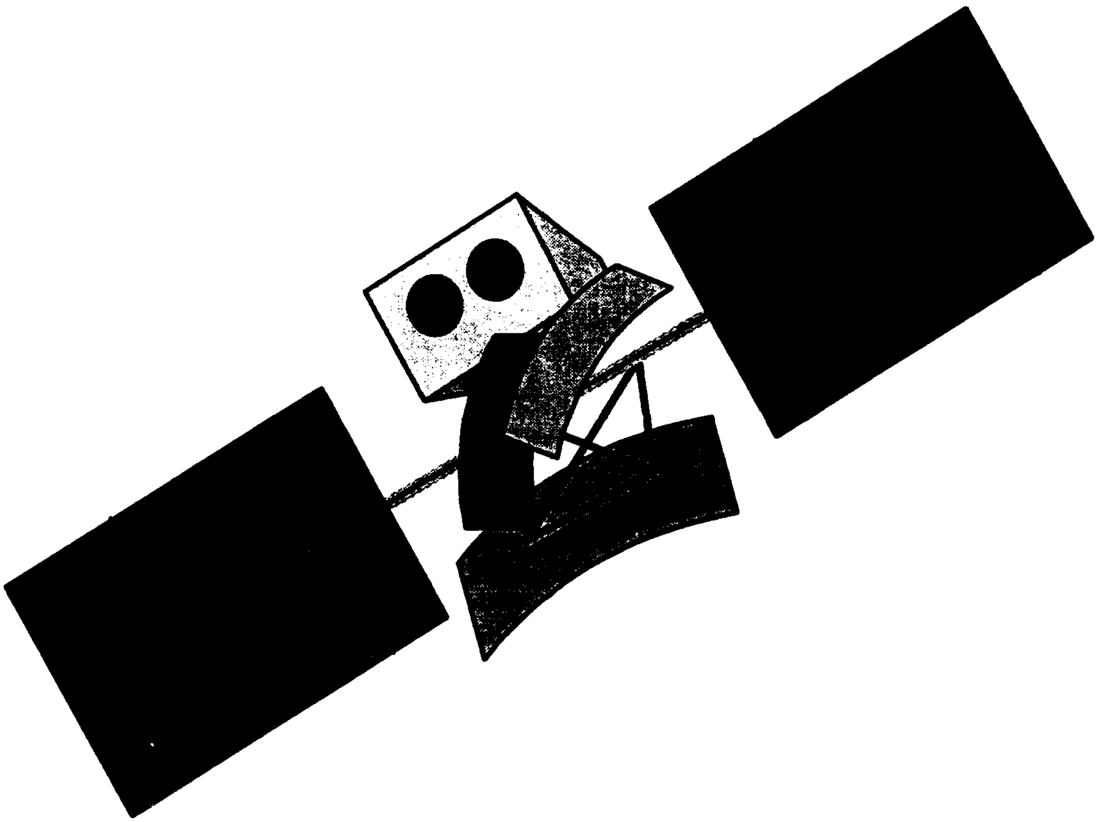
** WEIGHTED **   AIRCRAFT PROCUREMENT (3010)   OSD RATES   MARCH 1993

FISCAL YEAR	BASE YEAR 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.167	1.065	0.977	0.905	0.875	0.851	0.829	0.805	0.772	0.742	0.712	0.692	0.676
1982	1.228	1.121	1.028	0.952	0.921	0.896	0.872	0.847	0.813	0.781	0.749	0.729	0.712
1983	1.302	1.188	1.090	1.009	0.976	0.949	0.924	0.898	0.861	0.828	0.794	0.772	0.754
1984	1.358	1.239	1.136	1.052	1.018	0.990	0.964	0.936	0.898	0.864	0.828	0.805	0.786
1985	1.401	1.279	1.173	1.086	1.050	1.022	0.995	0.966	0.927	0.891	0.855	0.831	0.812
1986	1.452	1.325	1.215	1.125	1.088	1.059	1.031	1.001	0.961	0.924	0.886	0.861	0.841
1987	1.511	1.379	1.265	1.171	1.133	1.102	1.073	1.042	1.000	0.961	0.922	0.897	0.876
1988	1.586	1.447	1.328	1.229	1.189	1.157	1.126	1.093	1.049	1.009	0.967	0.941	0.919
1989	1.640	1.496	1.373	1.271	1.229	1.196	1.164	1.130	1.085	1.043	1.000	0.973	0.950
1990	1.689	1.541	1.413	1.309	1.266	1.231	1.199	1.164	1.117	1.074	1.030	1.002	0.978
1991	1.760	1.606	1.473	1.364	1.319	1.283	1.250	1.213	1.164	1.120	1.073	1.044	1.020
1992	1.778	1.622	1.488	1.378	1.332	1.296	1.262	1.225	1.176	1.131	1.084	1.055	1.030
1993	1.819	1.659	1.522	1.410	1.363	1.326	1.291	1.254	1.203	1.157	1.109	1.079	1.054
1994	1.860	1.697	1.557	1.442	1.394	1.356	1.321	1.282	1.230	1.183	1.134	1.103	1.079
1995	1.901	1.735	1.592	1.474	1.425	1.386	1.350	1.311	1.258	1.209	1.160	1.128	1.102
1996	1.943	1.773	1.627	1.506	1.457	1.417	1.380	1.340	1.286	1.236	1.185	1.153	1.126
1997	1.986	1.812	1.662	1.539	1.489	1.448	1.410	1.369	1.314	1.263	1.211	1.178	1.151
1998	2.030	1.852	1.699	1.573	1.521	1.480	1.441	1.399	1.343	1.291	1.238	1.204	1.176
1999	2.074	1.893	1.736	1.608	1.555	1.513	1.473	1.430	1.372	1.319	1.265	1.231	1.202
2000	2.120	1.934	1.775	1.643	1.589	1.546	1.505	1.461	1.402	1.348	1.293	1.258	1.228
2001	2.167	1.977	1.814	1.679	1.624	1.580	1.538	1.493	1.433	1.378	1.321	1.285	1.255
2002	2.214	2.020	1.854	1.716	1.660	1.615	1.572	1.526	1.465	1.408	1.350	1.314	1.283
2003	2.263	2.065	1.894	1.754	1.696	1.650	1.607	1.560	1.497	1.439	1.380	1.343	1.311
2004	2.313	2.110	1.936	1.793	1.734	1.686	1.642	1.594	1.530	1.471	1.410	1.372	1.340
2005	2.364	2.157	1.979	1.832	1.772	1.724	1.678	1.629	1.564	1.503	1.442	1.402	1.369
2006	2.416	2.204	2.022	1.872	1.811	1.761	1.715	1.665	1.598	1.537	1.473	1.433	1.400
2007	2.469	2.253	2.067	1.913	1.851	1.800	1.753	1.702	1.633	1.570	1.506	1.465	1.430
2008	2.523	2.302	2.112	1.956	1.891	1.840	1.791	1.739	1.669	1.605	1.539	1.497	1.462
2009	2.579	2.353	2.159	1.999	1.933	1.880	1.831	1.777	1.706	1.640	1.573	1.530	1.494
2010	2.635	2.405	2.206	2.043	1.975	1.922	1.871	1.817	1.743	1.676	1.607	1.563	1.527
2011	2.693	2.457	2.255	2.088	2.019	1.964	1.912	1.857	1.782	1.713	1.643	1.598	1.560
2012	2.753	2.511	2.304	2.133	2.063	2.007	1.954	1.897	1.821	1.751	1.679	1.633	1.595
2013	2.813	2.567	2.355	2.180	2.109	2.051	1.997	1.939	1.861	1.789	1.716	1.669	1.630
2014	2.875	2.623	2.407	2.228	2.155	2.096	2.041	1.982	1.902	1.829	1.753	1.706	1.666
2015	2.938	2.681	2.460	2.277	2.202	2.143	2.086	2.025	1.944	1.869	1.792	1.743	1.702
2016	3.003	2.740	2.514	2.327	2.251	2.190	2.132	2.070	1.987	1.910	1.831	1.782	1.740
2017	3.069	2.800	2.569	2.379	2.300	2.238	2.179	2.116	2.030	1.952	1.872	1.821	1.778
2018	3.137	2.862	2.625	2.431	2.351	2.287	2.227	2.162	2.075	1.995	1.913	1.861	1.817
2019	3.206	2.925	2.683	2.484	2.403	2.337	2.276	2.210	2.121	2.039	1.955	1.902	1.857
2020	3.276	2.989	2.742	2.539	2.456	2.389	2.326	2.258	2.167	2.084	1.998	1.944	1.898

Appendix K:

SBWAS Case

SPACE SYSTEM ESTIMATING USING AUTOMATED COST ESTIMATING INTEGRATED TOOLS (ACEIT)



Prepared by:
Captain Kerrie G. Schieman
Captain James R. Passaro

SCENARIO

On 15 June 1993, the Assisant Secretary of the Air Force, Financial Management and Comptroller (Deputy for Cost Analysis--SAF/FMC) sent a message to the Space and Missile Systems Center (SMC), at Los Angeles AFB, California, establishing the requirement for a Program Office Estimate (POE) on the Space Based Wide Area Surveillance (SBWAS) system. SAF/FMC designated SMC as the lead product center, with assistance to come from the Air Force Space Command in the area of Operations and Support (O&S), and the Air Force Engineering and Services Center in the area of facilities. The message was then routed to the SBWAS system program office. Since the SBWAS system was nearing the end of the Concept Exploration phase of the acquisition process, the purpose of the POE was to generate an estimate for the preferred SBWAS concept. While several alternative concepts were still being explored, the POE was only to address the preferred concept. The SBWAS program office immediately called a POE planning meeting to develop a methodology to conduct the estimating effort.

Captain John Franklin was one of several SMC Staff cost analysts who attended the initial POE planning session. John worked in the Research Branch of the Cost Analysis Division at SMC (SMC/FMCR). John's duties in the Research Branch had exposed him to a large number of cost models and other estimating tools used both at SMC and throughout the Air Force. But it was his expertise with a particular cost estimating tool that resulted in his presence at that meeting in June. For the last six months John had been working extensively with a software program developed by Tecolote, Inc., called Automated Cost Estimating Integrated Tools (ACEIT). While ACEIT had already become a popular estimating tool at the Electronic Systems Center (ESC), located at Hanscomb AFB, Massachusetts, Space and Missile Systems Center was in the process of exploring this program's applicability to estimating in the SMC environment.

John had heard rumors that ACEIT might be utilized to perform certain portions of the POE, but he was definitely surprised when it was announced at the meeting that ACEIT would be used to conduct the entire estimate. This represented a major shift for the SMC cost analysis staff--a shift in which John's experience with ACEIT would be playing a major part.

SBWAS PROGRAM BACKGROUND

The Space Based Wide Area Surveillance (SBWAS) program responds to Wide Area Surveillance (WAS) difficulties identified by the North American Aerospace Defense Command and the Unified and Specified Commanders in Chief. This program will provide for the acquisition of a reliable, high confidence, all weather, day and night, all terrain, global, space based system to provide WAS to complement the current and programmed surveillance systems operated by the warfighting commands.

HISTORY

The idea of conducting worldwide surveillance via space based sensors has existed and matured over the years. Several studies have explored the feasibility of such a system within the context of current and near-term technology developments. In 1984 the Defense Science Board (DSB) concluded that a modest Space Based Radar could be launched with existing technology. The DSB also recommended that current technology development programs continue to provide growth options. Several analysis efforts were subsequently launched, resulting in definitions and successive refinements to a range of SBWAS concepts to address existing operational requirements.

In 1991 the Defense Review Board tasked the Undersecretary of Defense for Acquisition (USD(A)) to convene the Defense Acquisition Board (DAB) and initiate the Milestone Zero process for an SBWAS system. The US Space Command prepared a Mission Need Statement (MNS) and the Joint Requirements Oversight Council subsequently approved the MNS prior to the Milestone Zero DAB review. The Milestone Zero DAB convened on 15 December 1991, resulting in authorization of the SBWAS program to proceed into the Concept Exploration phase. The DAB also directed the Navy and Air Force to conduct technology and concept definition efforts to support a Milestone I decision in July of 1993.

As a result of the concept exploration study analyses, the program office selected the center-fed rotating reflector concept as the SBWAS reference concept for cost estimating purposes.

SYSTEM DESCRIPTION

The Space Based Wide Area Surveillance system will provide worldwide surveillance from space of military systems. The intended targets include aircraft, surface ships, and cruise missiles. The present concept will provide real-time surveillance of areas far greater than current reconnaissance systems. This concept will allow for warning and targeting of enemy weapon systems to the theater commander. The SBWAS system will also extensively support strategic and tactical forces with timely threat data such as threat object heading, position, time of contact, potential identification, and an estimate of information quality.

The SBWAS system is composed of five segments: a space vehicle segment, a space connectivity segment, a ground segment, a user segment, and a launch segment.

Space Vehicle Segment. The space vehicle segment will consist of a system of orbiting satellites which contain surveillance sensors and necessary support systems. These satellites will employ radar sensors to detect and track targets. The SBWAS satellites will

CENTRAL-FED ROTATING REFLECTOR CONCEPT

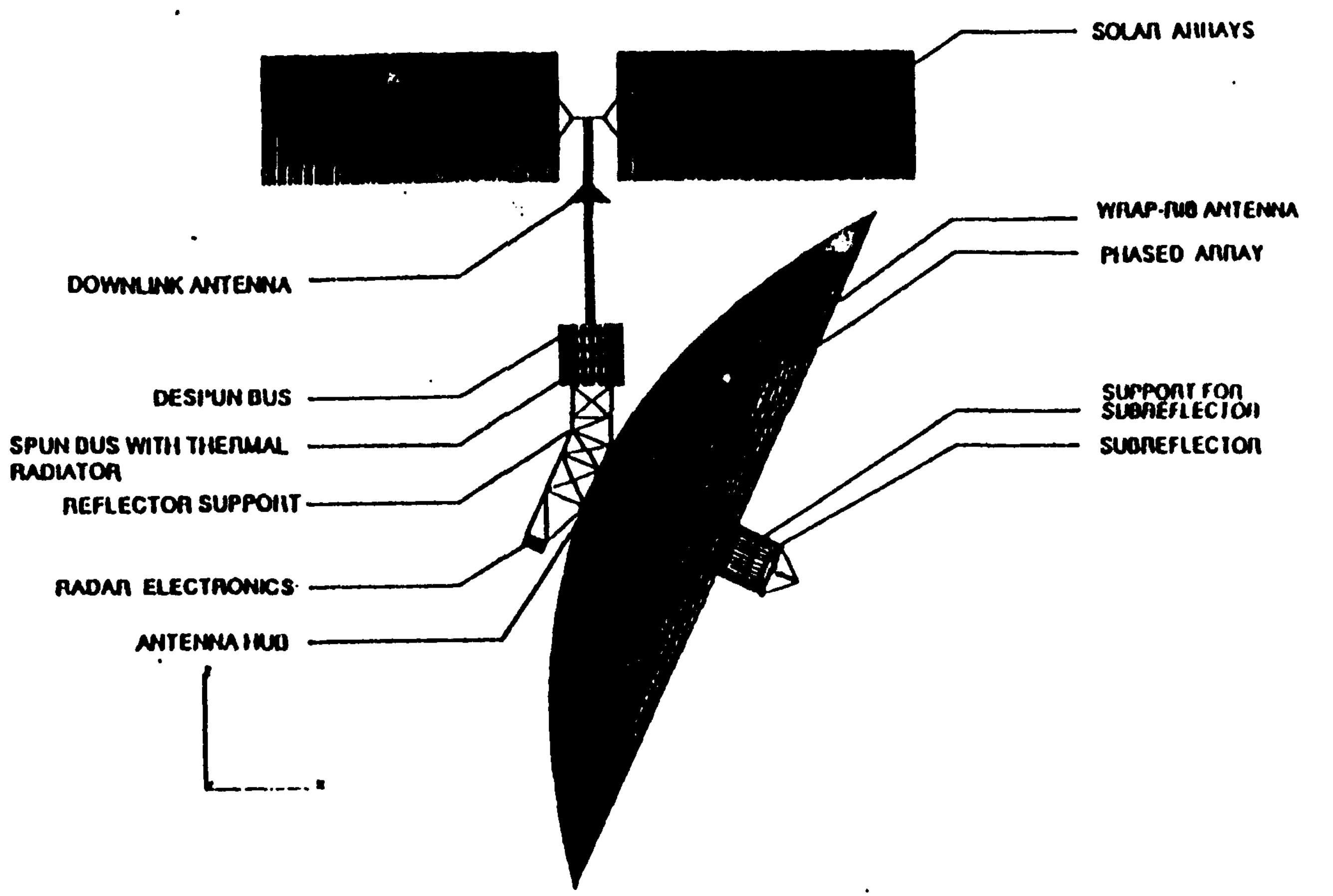


Figure 1.

SBWAS Reference Concept - Rotating Reflector

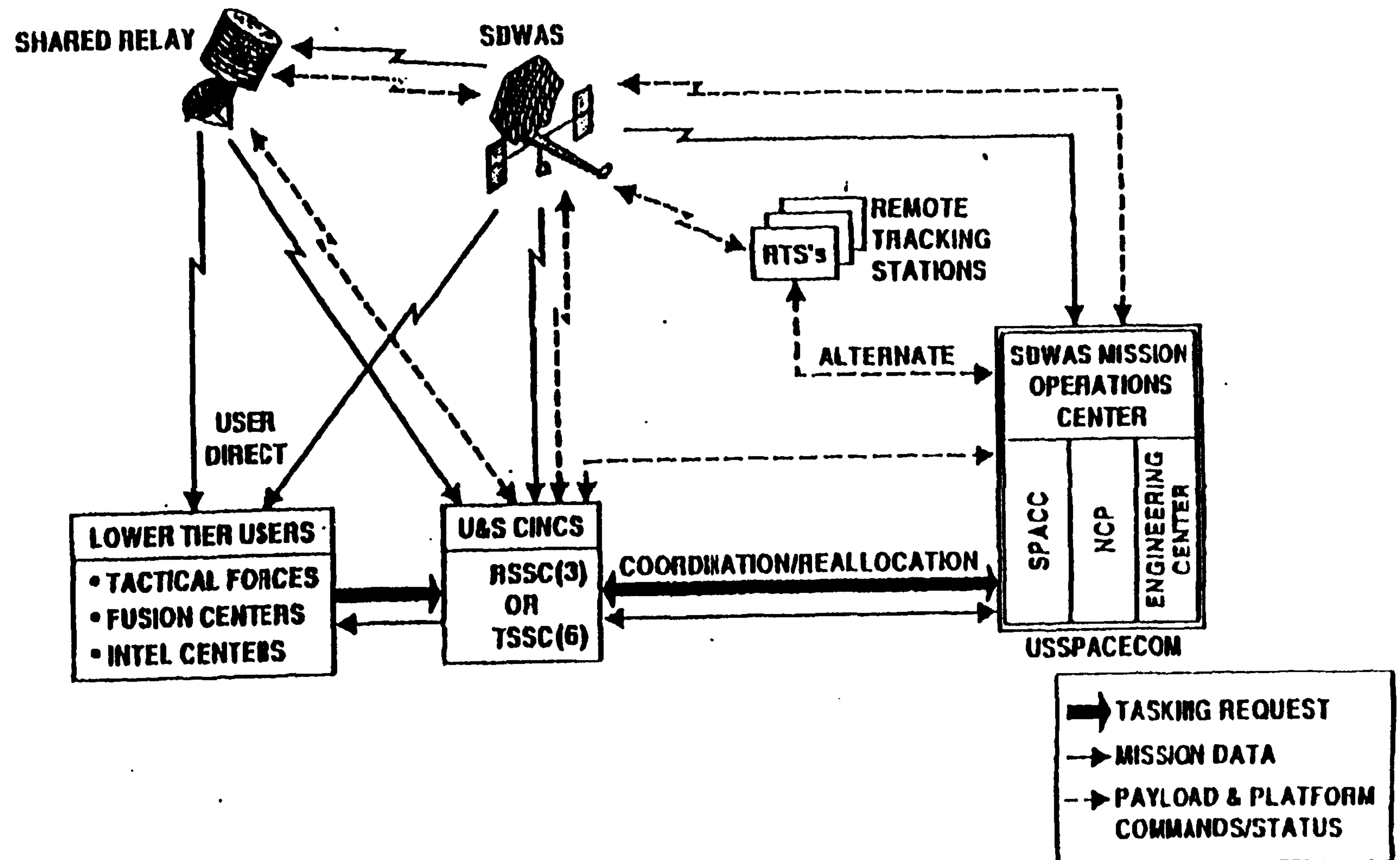


Figure 2.

SBWAS C^3 Architecture - Low Altitude

have, as a minimum, three communication antennas in addition to any radar payload antenna. These antennas will allow communications at three different frequencies: UHF, EHF, and SHF. The space vehicle consists of a spinning and a despun section. The spinning section contains the radar payload. The despun section contains the power, attitude, control, communications, and propulsion subsystems. Figure 1 illustrates the spacecraft configuration.

Telemetry, Tracking and Command (TT&C)/Communications. The TT&C/Communications is a subset of the Space Vehicle Segment and consists of four elements which are represented in both the Engineering and Manufacturing Development (EMD) and Production Space Vehicle Segment work breakdown structures (atch 1).

1. Transmitter/Amplifier - This element contains all the hardware associated with the design, development, and production of components that transmit telemetry and tracking data to ground stations via onboard antennas. The amplifier adds current to the signal thus making it more powerful and easier to receive.

2. Receiver/Exciter - This element contains all the hardware associated with the design, development, and production of components that receive via a spacecraft antenna commands and tracking queries transmitted from a ground station or from other satellites.

3. Digital Electronics - Contains all the hardware associated with the design, development, and production of components that recognize the presence of a signal, decrypt commands, and execute them. For telemetry, this subsystem processes the output data of mission related equipment onboard, performs an analog/digital conversion, encrypts messages, and oversees data transmission to the ground station. Typical components/units include base band units, general purpose computer, digital telemetry unit, command signal conditioning, command distribution unit, and software.

4. Analog Electronics - This element contains all the hardware associated with the design, development, and production of those hardware components that process analog waveforms/signals at intermediate/video frequencies down to direct current (DC). Typical components include intermediate frequency conditioning boxes, interface electronics, control electronics, and analog drivers.

Space Connectivity Segment. This segment will consist of a communications package on three planned geosynchronous relay satellites. This package will provide connectivity between the SBWAS satellites and the ground segment. The relays must be able to communicate with as many as three sensor satellites simultaneously. The package will be capable of transmitting and receiving EHF and S-band, and transmitting UHG through an omnidirectional antenna.

Ground Segment. The ground segment consists of the Command, Communication, and Control (C^3) nodes which will receive data for consumption or dissemination. The planned C^3 architecture is shown in figure 2. Mission data will be downlinked via relay satellite to a Mission Operations Centers (MOC), Regional Space Support Centers, and Transportable Space Support Centers--which are part of the ground segment structure--to support each of the Unified and Specified Commanders in Chief. Unlike the other segments, the ground segment will be procured with 3080 funds.

User Segment. The SBWAS will provide surveillance in support of strategic and tactical forces. In order to accomplish this task, SBWAS terminals or other existing user equipment may be located on ships, submarines, aircraft, and ground platforms. Thus the user segment consists of any modification or other additions to existing tactical user assets required for dissemination of processed track data.

Launch Segment. The launch segment consists of the Atlas IIAS launch vehicle system and any launch operations required to place a SBWAS satellite into operational orbit.

ACQUISITION APPROACH

The SBWAS Concept Exploration was initiated in 1991 by SMC at Los Angeles AFB, California. The total system acquisition plan will consist of the following phases:

Demonstration/Validation (Dem/Val). Dem/Val is a two year program beginning in 1993, with full and open competition for two contractors. The contractors selected for the Dem/Val effort are TRW and the Technical Science Corporation (TSC). All dollars expended in this phase will come from 3600 funds. The major emphasis of Dem/Val will be on ground demonstrations of the following key concept drivers:

1. Antenna model full aperture
2. Feed model - brassboard
3. Radar and data processing
4. Spacecraft scale model
5. Power distribution, voltage, and conditioning

Engineering and Manufacturing Development (EMD). EMD will be a five and one half year program starting in 1995. There will be one EMD contractor who will be responsible for building two EMD satellites (a qualification unit and a prototype unit). The EMD units will be procured with the 3600 appropriation.

Production. The production phase will be a four year program beginning in 1997. The fiscal year buy schedule is provided below. The production satellites are estimated to have a seven year life. One prime contractor will serve as the system integrator for the entire SBWAS system. There will be subcontractors for the radar payload, ground segment, and user interface segment. The production units will be procured with the 3020 appropriation (production schedule provided in the following table).

FY 97	FY98	FY99	FY00	TOTAL
0	1	2	2	5

Operations and Support (O&S). 12 O&S satellites will be produced to ensure that the constellation of 5 satellites is maintained. The O&S phase will cover a ten year system steady-state period, beginning in 2001. The O&S production units will be procured with 3020 funds. The O&S buy schedule is shown in the following table.

FY01	FY02	FY03	FY04	TOTAL
3	3	3	3	12

TASKING

John was appointed to the Space Vehicle estimating team. The specific responsibilities he was given were as follows:

1. Estimate the entire DEM/VAL phase, which includes technology costs (lab inputs), contractor costs (TRW inputs), and mission support (program office inputs). Provide abbreviated documentation of the Dem/Val estimate.

2. Utilize ACEIT to perform the following tasks:
   a. Estimate the non-recurring EMD costs for the TT&C/Communications subsystems.
   b. Estimate the Production costs for the TT&C/Communications subsystems.
   c. Perform sensitivity analysis on the cost elements you feel are the major cost drivers.
   d. Provide full documentation of the EMD and Production estimates.

3. Provide an explanation of the application of multiplicative correction factors used by ACEIT.

GROUND RULES & ASSUMPTIONS

1. All costs should be expressed in millions for both then year and base year dollars (FY91). OSD Inflation rates are provided at attachment 2.

2. Under the EMD and Production phases profit will be 12%, G&A will be 20%, and overhead will be 105%.

3. The EMD costs are spread based on the results of an SMC Beta curve model. These Beta values were selected as inputs for the SBWAS program since they are based on

actual contract history at SMC. From the model the shape parameters are: % Spent = 60; % Time = 40; Peakness = .3.

4. A 95% cumulative average cost improvement curve should be used to estimate the production recurring costs. This cost improvement curve is based on SMC experience with past space system contractors.

5. There is a lead time of one year for advance buy of the production units. The advance buy rate is 10% of the recurring production costs for the succeeding production buy. For example, the FY96 advance buy dollars are for the FY97 production buy.

RESEARCH EFFORT

Based on the tasking he received, John decided to start his estimating effort with the Dem/Val portion. His boss had previously given him the inputs from the various supporting laboratories (atch 3). He realized there were basically three cost elements in the Dem/Val estimate: a technology element based on the supporting laboratories, a contractor cost element provided by TRW, and a Mission Support element provided by the SBWAS program office. After examining each of the Dem/Val elements, John came up with the following descriptions.

Technology Element. The technology element contains support from the following laboratories: the Massachusetts Institute of Technology/Lincoln Laboratory (MIT/LL), Rome Air Development Center (RADC), the Air Force Geophysics Laboratory (AFGL), and the Air Force Astronautics Laboratory (AFAL). MIT/LL will be examining algorithm development, signal processor and transmitter/receiver (T/R) module test bed development, and near field test methodology. RADC will investigate high efficiency-high power S-band T/R modules, development reflector feed analysis, space qualified components, and system support. AFGL will be looking at propagation phenomenology: ionospheric field measurements, survey of existing ionospheric models, ionospheric effects analysis, and integration of results into a SBWAS simulator. AFAL will be examining battery and power technology issues.

Contractor Cost Element. This element includes tasks to be performed by two contractors: TRW and Technical Science Corporation (TSC). In the Concept Exploration phase several reference concepts were developed for the SBWAS system. The rotating reflector concept developed by TRW was selected to be the reference concept for the Dem/Val phase. Since TRWs initial efforts utilized a rotating reflector concept, their estimates of Dem/Val costs were used for this estimate. Specifically, several months ago TRW briefed their Dem/Val estimate to the SBWAS program office (John was in attendance). TRW developed a Dem/Val estimate of $59 million (BY91$) to complete the following tasks during the two year DEM/VAL phase: 1) key technology demonstrations including antenna feed tests, radar brassboard, beam forming adaptive processor simulation, reflector model demonstration, feed thermal concept demonstration, and beam agility demonstration; 2) system definition including system requirements, payload design, spacecraft design, and ground segment design; 3) reviews and reports. The estimate was based on one-half the work being subcontracted. In addition, TRW recommended an additional cost of 5% be added for Engineering Change Orders (ECO). TRW estimated a 65-35 percent phasing of contractor costs between fiscal years 93 and 94.

There is currently no estimate for TSCs Dem/Val efforts, but it is expected that their work will closely mirror TRW's efforts.

Mission Support Element. This element contains a baseline amount for Mission/Other Government Support in base year dollars. These amounts were determined by estimating program office manning, training, computer support, and travel expenses. John totaled these inputs and came up with a total mission support cost of $1 million per year (in base year 91 dollars) for the Dem/Val phase. John noted that these costs will significantly increase once the program moves into the EMD phase.

John realized that the DEM/VAL estimate would probably be the simplest task he would have to perform, so after gathering all the necessary DEM/VAL data, he turned his attention to the EMD and Production estimates. Knowing that ACEIT would be utilized to perform both the EMD and Production estimates, John decided that he needed to examine the cost estimating relationships (CERs) within ACEIT to determine what his data requirements would be.

After reviewing the ACEIT CER library, John discovered that the primary model used to estimate the TT&C/Communications segment was the "Unmanned Space Vehicle Cost Model (USCM) Sixth Edition," maintained at the SMC Cost Library. John had recently received an updated version of ACEIT from Tecolote, so he felt confident that the CERs were up to date. However, John recalled that another analyst on the SMC staff had worked on a satellite system which incorporated an EMD Receiver/Exciter (R/E) TT&C/Communications element. He decided to give this analyst a call and find out if she knew of any more recent data on the R/E element. The other analyst told him that she had recently collected some new R/E data points from various contractors. But she had not been able to run any kind of statistical tests on the data. Being familiar with ACEIT, John decided to use the COSTAT statistical function within ACEIT to test this new data set for possible use in his EMD estimate. The data set is provided on the following page. Below is a legend which defines the various parameters.

REXWT - The individual receiver/exciter weight in pounds.
LIFE - The space vehicle design life in months.
TOTAL COST - Total non-recurring costs (in BY91$) of the receiver/exciter in millions of dollars.

SYSTEM*	REXWT	LIFE	TOTAL COST($ in M)
SX-1	1.5	30	.99
SX-2	1.8	28	1.2
SX-3	54	78	2.5
SX-4	70	90	3.1
SX-5	32	20	1.5
SX-6	54	78	2.3
SX-7	28	50	1.75
SX-8	47	75	2.6
SX-9	40.8	57	2.2
SX-10	70.1	100	3.3
SX-11	35.7	48	1.9
SX-12	12.8	28	1.1
SX-13	40.5	65	2.1
SX-14	63	151	2.7
SX-15	10	54	1.4

*These systems are all classified programs and thus their names are concealed.

In order to use the ACEIT CER library John had to input the physical/performance parameters of the various TT&C/Communications elements. He therefore tasked the SBWAS engineers to provide these parameters for both the EMD and Production TT&C/Communications elements (atch 4).

The next obstacle for John was determining how to phase the costs of the EMD estimate. He knew that SMC usually employed Beta phasing as their [illegible]ary technique. However, John had recently received a Rand study which examined past contractor engineering manhour efforts for electronic systems. The study developed percentage spreads based on engineering manhours for EMD estimates from several analogous programs. Spreads were provided for several space system components, including separate spreads for both digital electronic and analog electronic systems. John checked with the appropriate engineers and discovered that the analogous programs used in the Rand study were in fact quite similar to the SBWAS system, so he made a copy of the digital and analog electronic spreads (provided below).

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6
DIGITAL	.10	.30	.35	.15	.08	.02
ANALOG	.20	.32	.25	.17	.06	--

After conducting this research John felt prepared to begin his estimating work.

Space Vehicle Segment EMD WBS

- 1.1 Space Vehicle Segment
  - 1.1.1 Space Vehicle PME/IA&T
  - 1.1.2 Space Vehicle Software Development
  - 1.1.3 Space Vehicle Radar Payload
  - 1.1.4 Space Vehicle Platform
    - 1.1.4.1 Crosslink Payload
      - 1.1.4.1.1 Crosslink Transponder
      - 1.1.4.1.2 Crosslink Digital Electronics
      - 1.1.4.1.3 Crosslink Analog Electronics
      - 1.1.4.1.4 Crosslink Antenna
    - 1.1.4.2 Spacecraft
      - 1.1.4.2.1 Spacecraft Structure
      - 1.1.4.2.2 Spacecraft Attitude Determination
      - 1.1.4.2.3 Spacecraft Reaction Control System
      - 1.1.4.2.4 Spacecraft Thermal Control
      - 1.1.4.2.5 EPS Power Generation
      - 1.1.4.2.6 EPS Power Storage
      - 1.1.4.2.7 EPS Conditioning Electronics
      - 1.1.4.2.8 TT&C/Communication Transmitter/Amplifier
      - 1.1.4.2.9 TT&C/Communication Receiver/Exciter
      - 1.1.4.2.10 TT&C/Communication Digital Electronics
      - 1.1.4.2.11 TT&C/Communication Analog Electronics
  - 1.1.5 Qualification Unit Refurbishment
  - 1.1.6 Prototype Unit
  - 1.1.7 Space Vehicle Level Non-PME Elements
    - 1.1.7.1 Aerospace Ground Equipment
    - 1.1.7.2 Flight Support Operations and Services
    - 1.1.7.3 Systems Engineering/Program Management
    - 1.1.7.4 Systems Test and Evaluation
    - 1.1.7.5 Data
    - 1.1.7.6 Fee

Space Vehicle Segment Production WBS

- 2.1 Space Vehicle Segment
  - 2.1.1 Space Vehicle PME IA&T
  - 2.1.2 Radar Payload
    - 2.1.2.1 Radar IA&T
    - 2.1.2.2 Reflector
    - 2.1.2.3 T/R Modules
    - 2.1.2.4 Beam Steering Computer
    - 2.1.2.5 Antenna Hub
    - 2.1.2.6 Transmitter Beam Forming Network
    - 2.1.2.7 Receiver Beam Forming Network
    - 2.1.2.8 Transmitter Group
      - 2.1.2.8.1 Transmitter
      - 2.1.2.8.2 Spoofing Transmitter
    - 2.1.2.9 Receiver
    - 2.1.2.10 Radar Electronics
    - 2.1.2.11 Signal Processor Group
      - 2.1.2.11.1 Front-End Processor
      - 2.1.2.11.2 Signal Processor
      - 2.1.2.11.3 Reaction Control System
      - 2.1.2.11.4 Thermal Control
      - 2.1.2.11.5 EPS Power Generation
      - 2.1.2.11.6 EPS Power Storage
      - 2.1.2.11.7 EPS Power Distribution
      - 2.1.2.11.8 EPS Power Conditioning Electronics
      - 2.1.2.11.9 TT&C/Communication Transmitter/Amplifier
      - 2.1.2.11.10 TT&C/Communication Receiver/Exciter
      - 2.1.2.11.11 TT&C/Communication Digital Electronics
      - 2.1.2.11.12 TT&C/Communication Analog Electronics
  - 2.1.3 Space Vehicle Level Non-PME Elements
    - 2.1.3.1 Flight Support Operations and Services
    - 2.1.3.2 Systems Engineering/Program Management
    - 2.1.3.3 Systems Test and Evaluation
    - 2.1.3.4 Data
    - 2.1.3.5 Fee

** RAW ** DEVELOPMENT (3600) OSD RATES MARCH 1993

FISCAL YEAR	1981	1982	BASE YEAR 1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.000	0.916	0.873	0.841	0.813	0.791	0.770	0.748	0.718	0.690	0.662	0.644	0.629
1982	1.092	1.000	0.953	0.918	0.888	0.864	0.841	0.817	0.784	0.754	0.723	0.703	0.686
1983	1.146	1.049	1.000	0.963	0.932	0.906	0.883	0.857	0.822	0.791	0.758	0.737	0.720
1984	1.189	1.089	1.038	1.000	0.967	0.941	0.916	0.889	0.854	0.821	0.787	0.765	0.747
1985	1.229	1.126	1.073	1.034	1.000	0.973	0.947	0.920	0.883	0.849	0.814	0.791	0.773
1986	1.264	1.157	1.103	1.063	1.028	1.000	0.974	0.945	0.907	0.872	0.836	0.814	0.795
1987	1.298	1.189	1.133	1.092	1.056	1.027	1.000	0.971	0.932	0.896	0.859	0.836	0.816
1988	1.337	1.224	1.167	1.124	1.087	1.058	1.030	1.000	0.960	0.923	0.885	0.861	0.840
1989	1.393	1.276	1.216	1.172	1.133	1.102	1.073	1.042	1.000	0.962	0.922	0.897	0.876
1990	1.449	1.327	1.265	1.218	1.178	1.146	1.116	1.084	1.040	1.000	0.959	0.933	0.911
1991	1.511	1.384	1.319	1.271	1.229	1.196	1.164	1.130	1.085	1.043	1.000	0.973	0.950
1992	1.553	1.423	1.356	1.306	1.264	1.229	1.197	1.162	1.115	1.072	1.028	1.000	0.977
1993	1.591	1.457	1.389	1.338	1.294	1.259	1.226	1.190	1.142	1.098	1.053	1.024	1.000
1994	1.629	1.492	1.422	1.370	1.325	1.289	1.255	1.218	1.169	1.124	1.078	1.049	1.024
1995	1.666	1.526	1.455	1.401	1.355	1.318	1.284	1.246	1.196	1.150	1.103	1.073	1.048
1996	1.705	1.561	1.488	1.434	1.387	1.349	1.313	1.275	1.224	1.177	1.128	1.097	1.072
1997	1.742	1.595	1.521	1.465	1.417	1.378	1.342	1.303	1.251	1.202	1.153	1.122	1.095
1998	1.781	1.631	1.554	1.497	1.448	1.409	1.372	1.332	1.278	1.229	1.178	1.146	1.119
1999	1.820	1.666	1.589	1.530	1.480	1.440	1.402	1.361	1.306	1.256	1.204	1.171	1.144
2000	1.860	1.703	1.623	1.564	1.513	1.471	1.433	1.391	1.335	1.284	1.231	1.197	1.169
2001	1.901	1.741	1.659	1.598	1.546	1.504	1.464	1.422	1.364	1.312	1.258	1.224	1.195
2002	1.942	1.779	1.696	1.634	1.580	1.537	1.496	1.453	1.394	1.341	1.285	1.250	1.221
2003	1.985	1.818	1.733	1.670	1.615	1.571	1.529	1.485	1.425	1.370	1.314	1.278	1.248
2004	2.029	1.858	1.771	1.706	1.650	1.605	1.563	1.518	1.456	1.400	1.343	1.306	1.275
2005	2.074	1.899	1.810	1.744	1.687	1.641	1.597	1.551	1.488	1.431	1.372	1.335	1.303
2006	2.119	1.941	1.850	1.782	1.724	1.677	1.633	1.585	1.521	1.463	1.402	1.364	1.332
2007	2.166	1.983	1.891	1.821	1.762	1.714	1.669	1.620	1.555	1.495	1.433	1.394	1.361
2008	2.213	2.027	1.932	1.861	1.800	1.751	1.705	1.656	1.589	1.528	1.465	1.425	1.391
2009	2.262	2.072	1.975	1.902	1.840	1.790	1.743	1.692	1.624	1.561	1.497	1.456	1.422
2010	2.312	2.117	2.018	1.944	1.880	1.829	1.781	1.729	1.659	1.596	1.530	1.488	1.453
2011	2.363	2.164	2.063	1.987	1.922	1.869	1.820	1.767	1.696	1.631	1.564	1.521	1.485
2012	2.415	2.211	2.108	2.031	1.964	1.911	1.860	1.806	1.733	1.667	1.598	1.554	1.518
2013	2.468	2.260	2.154	2.075	2.007	1.953	1.901	1.846	1.771	1.703	1.633	1.589	1.551
2014	2.522	2.310	2.202	2.121	2.051	1.996	1.943	1.886	1.810	1.741	1.669	1.624	1.586
2015	2.578	2.360	2.250	2.168	2.097	2.039	1.986	1.928	1.850	1.779	1.706	1.659	1.620
2016	2.634	2.412	2.300	2.215	2.143	2.084	2.029	1.970	1.891	1.818	1.743	1.696	1.656
2017	2.692	2.465	2.350	2.264	2.190	2.130	2.074	2.014	1.933	1.858	1.782	1.733	1.692
2018	2.751	2.520	2.402	2.314	2.238	2.177	2.120	2.058	1.975	1.899	1.821	1.771	1.730
2019	2.812	2.575	2.455	2.365	2.287	2.225	2.166	2.103	2.019	1.941	1.861	1.810	1.768
2020	2.874	2.632	2.509	2.417	2.338	2.274	2.214	2.150	2.063	1.984	1.902	1.850	1.807
2021	2.937	2.690	2.564	2.470	2.389	2.324	2.263	2.197	2.108	2.027	1.944	1.891	1.846
2022	3.002	2.749	2.620	2.524	2.441	2.375	2.313	2.245	2.155	2.072	1.986	1.932	1.887
2023	3.068	2.809	2.678	2.580	2.495	2.427	2.363	2.295	2.202	2.117	2.030	1.975	1.929
2024	3.135	2.871	2.737	2.637	2.550	2.481	2.415	2.345	2.251	2.164	2.075	2.018	1.971
2025	3.204	2.934	2.797	2.695	2.606	2.535	2.469	2.397	2.300	2.212	2.120	2.063	2.014
2026	3.275	2.999	2.859	2.754	2.664	2.591	2.523	2.449	2.351	2.260	2.167	2.108	2.059

** WEIGHTED ** DEVELOPMENT (3600) OSD RATES MARCH 1993

FISCAL YEAR	BASE YEAR 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1981	1.044	0.956	0.911	0.878	0.849	0.826	0.804	0.781	0.749	0.721	0.691	0.672	0.656
1982	1.116	1.022	0.974	0.939	0.908	0.883	0.860	0.835	0.801	0.770	0.739	0.718	0.702
1983	1.168	1.069	1.019	0.982	0.950	0.924	0.900	0.873	0.838	0.806	0.773	0.752	0.734
1984	1.213	1.111	1.059	1.020	0.987	0.960	0.935	0.907	0.871	0.837	0.803	0.781	0.763
1985	1.254	1.148	1.095	1.055	1.020	0.992	0.966	0.938	0.900	0.866	0.830	0.807	0.788
1986	1.284	1.176	1.121	1.080	1.045	1.016	0.990	0.961	0.922	0.887	0.850	0.827	0.807
1987	1.343	1.230	1.172	1.129	1.092	1.062	1.035	1.004	0.964	0.927	0.889	0.864	0.844
1988	1.386	1.269	1.210	1.166	1.127	1.097	1.068	1.037	0.995	0.957	0.917	0.892	0.871
1989	1.432	1.311	1.250	1.204	1.165	1.133	1.103	1.071	1.028	0.988	0.947	0.922	0.900
1990	1.489	1.363	1.300	1.252	1.211	1.178	1.147	1.114	1.069	1.028	0.985	0.958	0.936
1991	1.543	1.413	1.347	1.298	1.255	1.221	1.189	1.154	1.108	1.065	1.021	0.993	0.970
1992	1.581	1.448	1.380	1.329	1.286	1.251	1.218	1.182	1.135	1.091	1.046	1.018	0.994
1993	1.618	1.482	1.413	1.361	1.316	1.281	1.247	1.211	1.162	1.117	1.071	1.042	1.017
1994	1.656	1.517	1.446	1.393	1.347	1.311	1.276	1.239	1.189	1.143	1.096	1.066	1.041
1995	1.694	1.551	1.479	1.425	1.378	1.340	1.305	1.267	1.216	1.169	1.121	1.091	1.065
1996	1.732	1.586	1.512	1.457	1.409	1.371	1.335	1.296	1.244	1.196	1.146	1.115	1.089
1997	1.770	1.621	1.546	1.489	1.440	1.401	1.364	1.324	1.271	1.222	1.172	1.140	1.113
1998	1.809	1.657	1.580	1.522	1.472	1.432	1.394	1.353	1.299	1.249	1.197	1.165	1.137
1999	1.849	1.693	1.614	1.555	1.504	1.463	1.425	1.383	1.327	1.276	1.224	1.190	1.162
2000	1.890	1.731	1.650	1.589	1.537	1.495	1.456	1.414	1.357	1.304	1.251	1.217	1.188
2001	1.931	1.769	1.686	1.624	1.571	1.528	1.488	1.445	1.386	1.333	1.278	1.243	1.214
2002	1.974	1.808	1.723	1.660	1.606	1.562	1.521	1.476	1.417	1.362	1.306	1.271	1.241
2003	2.017	1.847	1.761	1.697	1.641	1.596	1.554	1.509	1.448	1.392	1.335	1.299	1.268
2004	2.062	1.888	1.800	1.734	1.677	1.631	1.588	1.542	1.480	1.423	1.364	1.327	1.296
2005	2.107	1.930	1.839	1.772	1.714	1.667	1.623	1.576	1.513	1.454	1.394	1.356	1.325
2006	2.153	1.972	1.880	1.811	1.752	1.704	1.659	1.611	1.546	1.486	1.425	1.386	1.354
2007	2.201	2.015	1.921	1.851	1.790	1.741	1.696	1.646	1.580	1.519	1.456	1.417	1.384
2008	2.249	2.060	1.964	1.892	1.829	1.780	1.733	1.682	1.615	1.552	1.488	1.448	1.414
2009	2.299	2.105	2.007	1.933	1.870	1.819	1.771	1.719	1.650	1.587	1.521	1.480	1.445
2010	2.349	2.151	2.051	1.976	1.911	1.859	1.810	1.757	1.686	1.622	1.555	1.512	1.477
2011	2.401	2.199	2.096	2.019	1.953	1.900	1.850	1.796	1.724	1.657	1.589	1.546	1.509
2012	2.454	2.247	2.142	2.064	1.996	1.942	1.890	1.835	1.761	1.694	1.624	1.580	1.543
2013	2.508	2.297	2.189	2.109	2.040	1.984	1.932	1.876	1.800	1.731	1.660	1.614	1.577
2014	2.563	2.347	2.237	2.156	2.085	2.028	1.975	1.917	1.840	1.769	1.696	1.650	1.611
2015	2.619	2.399	2.287	2.203	2.131	2.072	2.018	1.959	1.880	1.808	1.733	1.686	1.647
2016	2.677	2.451	2.337	2.251	2.177	2.118	2.062	2.002	1.922	1.848	1.772	1.723	1.683
2017	2.736	2.505	2.388	2.301	2.225	2.165	2.108	2.046	1.964	1.888	1.811	1.761	1.720
2018	2.796	2.561	2.441	2.352	2.274	2.212	2.154	2.091	2.007	1.930	1.850	1.800	1.758
2019	2.858	2.617	2.495	2.403	2.324	2.261	2.202	2.137	2.051	1.972	1.891	1.840	1.796
2020	2.920	2.674	2.550	2.456	2.375	2.311	2.250	2.184	2.096	2.016	1.933	1.880	1.836

LAB INPUT

Facility: Massachusetts Institute of Technology (MIT/LL)

Focal Point: John Handrick

Description: Experimental investigation of ECCM techniques and algorithm development, signal processor and transmitter/receiver module test bed development, and near field test methodology.

Cost Data: ($ in BY91)

	FY93	FY94
Labor Hours	164,000	119,000
Composite Labor Rate ($/Hour)	71	71
Total Cost ($ in millions)	11,644,000	8,449,000

Note: The composite rate includes direct labor, other direct costs, and indirect/overhead costs.

LAB INPUT

Facility: Rome Air Development Center

Focal Point: Janet Evans

Description: Investiagation and verification of high-efficiency-high power S-band T/R modules, development reflector feed analysis, and space qualified components.

Cost Data:($ in BY91)

	FY93	FY94
Labor Hours	33,000	34,000
Composite Labor Rate ($/Hour)	56	56
Total Cost ($ in millions)	1,848,000	1,904,000

Note: The composite rate includes direct labor, and other direct costs. Indirect/Overhead costs are not included in the composite rate because this is an Air Force Facility.

LAB INPUT

Facility: Air Force Geophysics Laboratory (AFGL)

Focal Point: Manfred Kamden

Description: Examination of propagation phenomenology pertaining to ionospheric field measurements, ionoshperic models, and ionospheric effects analysis. Results will be integrated into a SBWAS simulator.

Cost Data:($ in BY91)

	FY93	FY94
Labor Hours	37,000	18,000
Composite Labor Rate ($/Hour)	53	53
Total Cost ($ in millions)	1,961,000	954,000

Note: The composite rate includes direct labor, and other direct costs. Indirect/Overhead costs are not included in the composite rate because this is an Air Force Facility.

LAB INPUT

Facility: Air Force Astronautics Laboratory (AFAL)

Focal Point: Jennifer Robinson

Description: Experimental investigation of battery and power technology.

Cost Data:($ in BY91)

	FY93	FY94
Labor Hours	5,250	4,100
Composite Labor Rate ($/Hour)	54	54
Total Cost ($ in millions)	283,500	221,400

Note: The composite rate includes direct labor, and other direct costs. Indirect/Overhead costs are not included in the composite rate because this is an Air Force Facility.

ENGINEERING INPUT

Transmitter/Amplifier (T/A)

There are three types of T/As in the TT&C/Communications subsystem: an S-band transmitter, a Beacon transmitter, and a UHF transmitter.

S-Band Transmitter Radio Frequency Power Output (RPOW) - 19.5 watts
Beacon Transmitter RPOW - 1.35 watts
UHF Transmitter RPOW - 22.75 watts
Telemetry, Tracking, and Command T/A Suite Componenet Weight (TTAWT) - 8.4 lbs
Communications T/A Suite Component Weight (CTAWT) - 6.32 lbs

Receiver/Exciters (R/E)

There are two different types of R/Es in the TT&C/Communications subsystem: a command receiver and a master timer.

Command R/E Weight (REXWT) - 5.23 lbs
Master Timer R/E Weight (REXWT) - 3.52 lbs
Space Vehicle Design Life - 83 months

Digital Electronics (DE)

There are three different types of digital electronic components in the TT&C/Communications susbsystem: a KG-57 unit, an HS-57 unit, and a Command/Telemetry unit.

KG-57 DE Component Power Required (DEPOW) - 8 watts
HS-57 DEPOW - 8 watts
Command/Telemetry DEPOW - 48 watts
KG-57 Communications DE Box Weight (CDEWT) - 4.25 lbs
HS-57 CDEWT - 3.95 lbs
Command/Telemetry CDEWT - 11.38 lbs

For production, there will be 4 KG-57 units, 2 HS-57 units, and 1 Command/Telemetry unit in the TT&C/Communications subsystem.

Analog Electronics (AE)

Total Analog Electronics Suite Weight (AESWT) - 25.3 lbs
Sum of Unique AE Component Weights (UAEWT) - 14.7 lbs

Other Performance Considerations

In addition to the above parameters, there are several performance considerations which may impact the overall cost of the TT&C/Communications system.

The T/A subsystem does not have a TWTA Technology Component (TWT), and the T/A component can be categorized as a communications type subsystem. The R/E subsystem will operate in a synchronous orbit. Additionally, the mission of the analog electronics subsystem can be categorized as a communications mission.

<u>Bibliography</u>

1. Rolando, John A. and Dr Robert T. Butcher. "Is There Going to be a High-tech Air Force in the Future?" <u>Program Manager Magazine</u>, 21:2-7 (June 1992).

2. Congress of the United States, Office of Technology Assessment. <u>Building Future Security: Strategies for Restructuring the Defense Technology and Industrial Base</u>. GPO, Washington DC, June 1992.

3. Stewart, Rodney D. <u>Cost Estimating</u>. New York: John Wiley and Sons, Inc., 1991.

4. Stein, Jess and Lawrence Urday. <u>The Random House Dictionary of the English Language</u>. New York: Random House, Inc., 1967.

5. Gove, Philip Babcock. <u>Webster's Third New International Dictionary of the English Language</u>. Springfield MA, G&C Merriam Company, 1966.

6. Simpson, Wendell P. Graduate Cost Analysis Program Manager, Air Force Institute of Technology, Wright-Patterson AFB OH. Personal Interviews, October 1992-June 1993.

7. Simpson, Wendell P. Class handout, Introduction to Cost Analysis. School of Logistics and Acquisition Management, Air Force Institute of Technology, Wright-Patterson AFB OH, June 1992.

8. The Analytical Sciences Corporation (TASC). <u>Air Force Systems Command Cost Estimating Handbook</u>. One Jacob Way, Reading MA.

9. Nethery, John J. Deputy Assistant Secretary of the Air Force, Plans, Systems, and Analysis, Pentagon, Washington DC, "Training Requirements for Acquisition Personnel in the Business, Cost Estimating, and Financial Management Position Category." Report to all Major Command Comptrollers, 14 July 1993.

10. Leenders, Michiel R. and James A. Erskine. <u>Case Research: The Case Writing Process</u>. London ON. Schawb School of Business Administration, University of Western Ontario, 1989.

11. Safavi, Farokh. "Informatice: The Incomplete-Information Approach to Case Administration," <u>Management International Review</u>, 18:99-107 (1978).

12. Kelly, Helen. "Case Method Training: What is it, How it Works," <u>Training</u>, 20:46-49 (February, 1983).

13. Kreck, Lothar A. "Operational Problem Solving: Overcoming a Weakness of the Case Method," Cornell Hotel and Restaurant Administration Quarterly, 3:69-72 (August 1992).

14. Takekuwa, Laura. Budget Course Manager, Department of the Navy, Human Resources Office, Crystal City VA. Telephone Interview, 10 August 1993.

15. Air Force Institute of Technology. AFIT Professional Continuing Education Catalog. 9th Edition 35-69. Wright-Patterson AFB OH.

16. Danneman, Jeffrey. Associate Professor of Quantitative Management, Air Force Institute of Technology, Wright-Patterson AFB OH. Personal interview, 10 Mar 1993, 7 May 1993.

18. Allen, John. Deputy Chief, Program Control, C-17 Program Office, Wright-Patterson AFB OH. Personal Interview, 17 Jan 1993.

19. Tracht, Tom. Instructor of Quantitative Management, Air Force Institute of Technology, Wright-Patterson AFB OH. Personal interview, 23 Jan 1993.

20. Bloom, Benjamin S. Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain. New York: David McKay Company, Inc., 1956.

21. Leenders, Michiel R. Class Handout, National Association of Purchasing Management (NAPM), Case Writing in Purchasing Workshop. Portland State University, Portland OR, September 1989.

22. Miles, Matthew B., and A. Michael Huberman. Qualitative Data Analysis, A Source Book of New Methods. Beverly Hills CA. SAGE Publications Inc., 1984.

23. The Analytical Sciences Corporation (TASC). Low-Altitude Navigation Targeting Infrared for Night (LANTIRN) System Independent Cost Estimate. Number TR-3612-5-1, Reading MA, 1981.Dayton OH, 1981.

24. Aeronautical Systems Division (ASD/YCPF). C-17 1988 Annual Estimate. Wright-Patterson AFB OH, 1988.

25. Aeronautical Systems Division (ASD/ACCC). C-17 Independent Cost Analysis. Wright-Patterson AFB OH, 1988.

26. Oleson, Paul E. and others. Space Based Wide Area Surveillance (SBWAS) Single Best Estimate. Volume II, CR-0447. Tecolote Research, Inc., Manhattan Beach CA, 1988.

Vita

Captain James R. Passaro was born on 13 October 1964 in Buffalo, New York. He graduated from high school in Miami, Florida, in 1982, and received a Bachelor of Science from the United States Air Force Academy in 1986. He was subsequently assigned to Moody AFB, Georgia, as Chief of the Cost Analysis Branch. In July of 1989 he was selected to be an Instructor at Sheppard AFB, Texas, where he taught in both the Cost Analysis Officer and Comptroller Staff Officer courses. While at Sheppard Captain Passaro received a Masters of Business Administration (MBA) from Oklahoma City University. In May of 1992 he entered the School of Logistics and Acquisition Management at the Air Force Institute of Technology. He is married to the former Lori Ann Cray, and they have two sons--Ryan and Kristian. Their third child, a daughter, is due to be born in October of this year. So you can see he accomplished much more at AFIT than just completing a thesis.

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Vita

Captain Kerrie G. Schieman was born on 15 June 1964 in Portsmouth, New Hampshire. She graduated from West Springfield High School in Virginia in 1982, and received a Bachelor of Arts (Accounting) from the University of Cincinnati in 1986. She was subsequently assigned to Wright-Patterson AFB as a Financial Manager in the Aeronautical Systems Center Propulsion System Program Office (SPO). In March of 1989 she was assigned to the C-17 SPO, where she performed duties as a cost analyst until entering the School of Logistics and Acquisition Management, Air Force Institute of Technology, in May 1992. In March of 1993 she was married to John B. Schieman.

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13. ABSTRACT (Maximum 200 words) The goal of this research effort was to develop educational cases that would bridge the gap between the theory and principles of cost estimating currently taught in the Air Force Institute of Technology (AFIT) Graduate Cost Analysis (GCA) curriculum and the real world of cost estimating in the acquisition arena. To achieve these goals, the following research objectives were investigated: (1) Identify cost estimating skills that graduates of the AFIT GCA curriculum are expected to possess. (2) Assess the relative importance of the identified cost estimating skills. (3) Select weapon system scenarios that are relevant, interesting and facilitate student performance of identified cost estimating skills. (4) Provide cases based on realistic scenarios that will facilitate student learning of important cost estimating skills. The cases developed in this research effort were implemented in the summer quarter 1993 GCA seminar class. Feedback from seminar students and Air Force cost estimating organizations was collected to measure the overall effectiveness of these cases in facilitating student learning. The results show that the cases developed in this effort are effective in developing the AFIT GCA students' abilities to apply cost estimating techniques.

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3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Please estimate what this research would have cost in terms of manpower and/or dollars if it had been accomplished under contract or if it had been done in-house.

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